COMBUSTION

Vol. 5, No. 3 SEPTEMBER, 1933 25c a copy

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Fan Maintenance

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A Review of Recent European Boiler Designs

Announcing Another Improvement in Ljungstrom Heating Surface

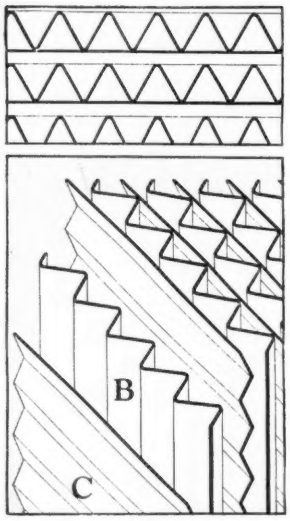


Fig. 1. The old Ljungstrom Heating Surface. Crimped plates C having undulations crosswise of the corrugations of plates B.

Increased capacity; highest known heat transfer rate from regenerative surface; much lower resistance to fluid flow. And for given delivery, smaller preheater volume, weight and fan power requirement.

The type of heating surface (Fig. 1) used in Ljungstrom Preheaters for the past five years has met service requirements well and from every standpoint would justify continuance without change. But—the constant determination to still further increase Ljungstrom supremacy has inspired continuous effort to secure still higher heat transfer, still lower resistance to fluid flow, and still greater freedom from soot and fly ash deposit.

The improved heating surface, Fig. 2, is conspicuous for extreme openness of the passages, greater turbulence of fluid flow, and an added whirl of the gases which forces them into closer contact with the metal and unifies temperature throughout the stream.

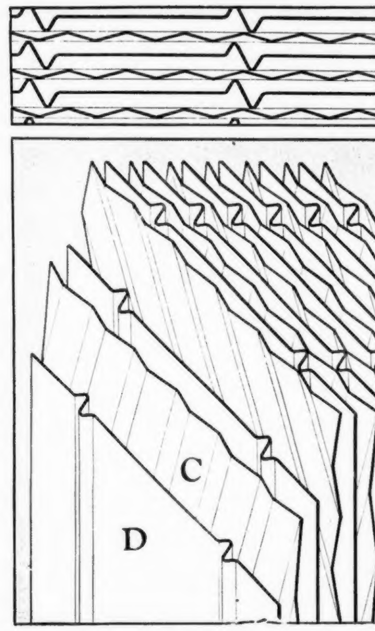


Fig. 2. The new Ljungstrom Heating Surface. Crimped plates C with their undulations sloping at 30 deg. to the path of fluid travel and in opposite directions in alternating sheets. Companion sheets D flat with spacing ribs to form wide longitudinal passages with plates far enough apart to give large sectional area to the passages. This latest design has only one-third as many heating passages, which are three times as large and contain no surface contacts or wedge-shaped places where soot and ash might tend to lodge.

The decrease in resistance, as shown in Fig. 3, correspondingly reduces the draft fan power requirements or with given forced-draft and induced-draft fans permits an appreciable preheater capacity increase. Actual service in an outstanding Eastern public utility plant, where the new surface was substituted for the old in an installation, has resulted in even greater decrease in resistance than indicated in the curves.

The new high-capacity low-resistance heating surface affords the second important reduction in Ljungstrom Preheater size, weight and investment and operating costs for given duty. It still further increases the profitableness of preheat in large plants, and extends its range of practicability down to smaller boiler units and further into plants with the lower load and use factors. In the latter instances, it makes preheat now desirable where with previous heating surface, the equipment expense was hard to justify.

Also as the new surface is interchangeable with the old, existing Ljungstrom Preheater installations can be substantially improved in recovery and capacity by making the change. For further details, send for our new Bulletin 633.

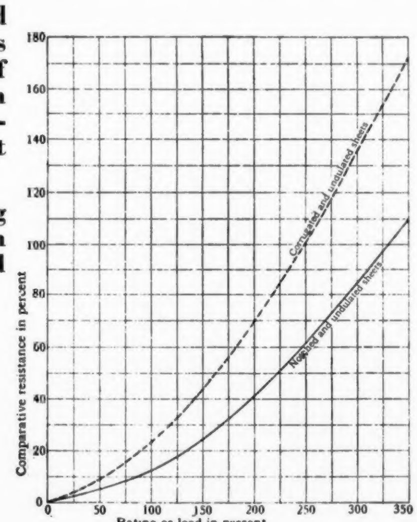
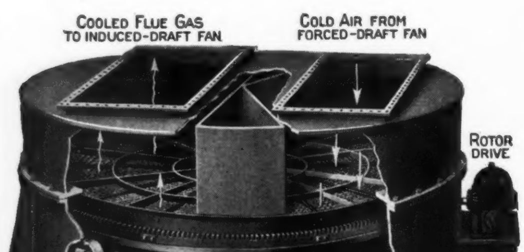


Fig. 3. Comparison of resistance in old (dotted line) and new (solid line) types of Ljungstrom Heating Surface. For preheaters of equal heat transfer capacity, the resistance with the new type notched and undulated plates is only about 60 per cent of that with the old corrugated and undulated plates.



Type CANX, for use with independent forced-draft and induced-draft fans.

Operated with rack-and-pinion drive, and has a center thrust bearing in the cold air side of the top housing. For boiler units of 1000 hp. and over.

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COMBUSTION

VOLUME FIVE • NUMBER THREE

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Combustion is published monthly by In-Ce-Co Publishing Corporation, a subsidiary of International Combustion Engineering Corporation, 200 Madison Avenue, New York. London office, Aldwych House, Aldwych, W.C.2. Frederic A. Schaff, President; Charles McDonough, Vice-President; G. W Grove, Secretary; H. H. Berry, Treasurer. Subscriptions, including postage, United States, $2.00, Great Britain, $2.50 a year. Canada, $3.00 (includes Canadian tax). Other countries, $3.00 Single copies: 25 cents.

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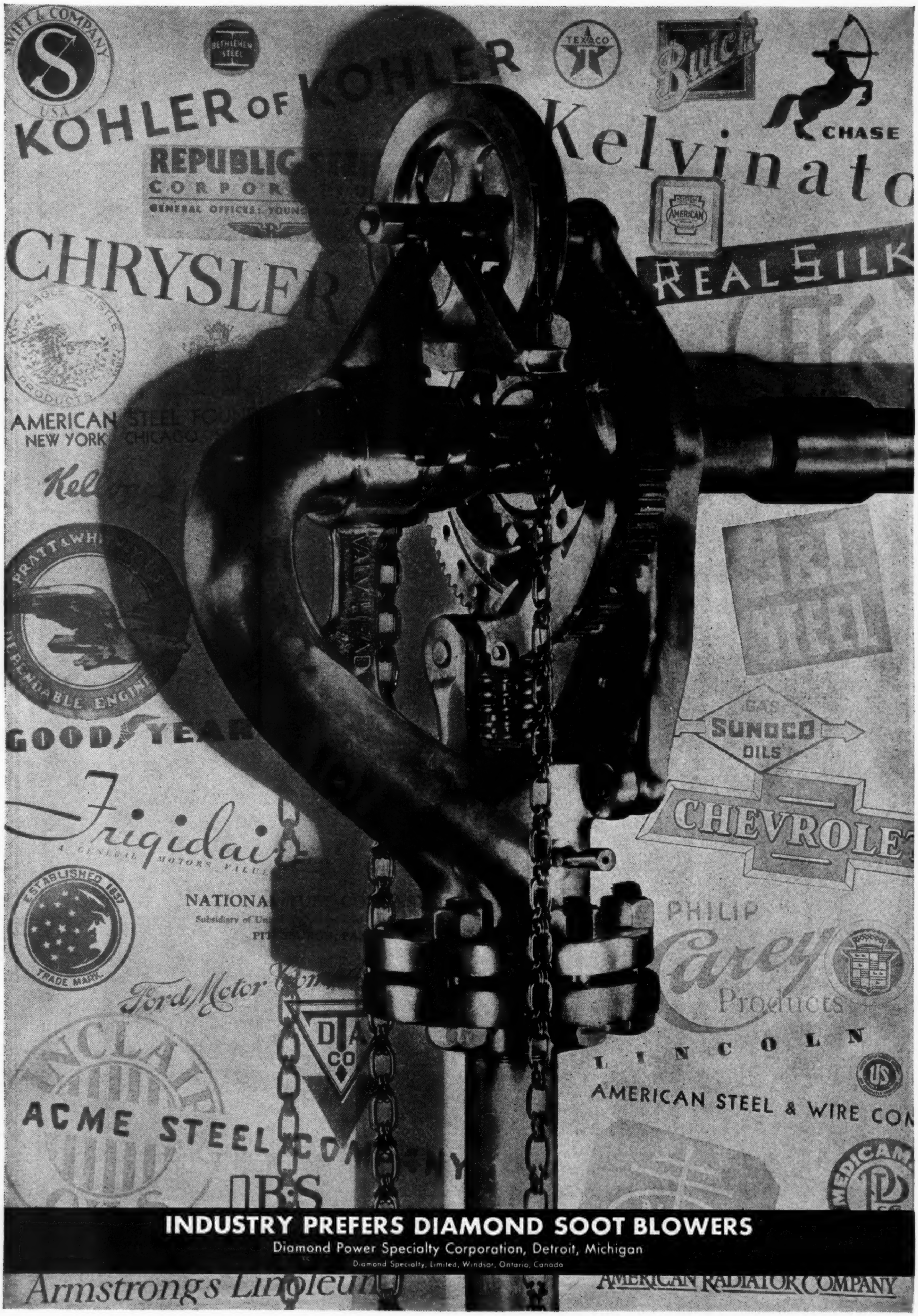
Printed in U.S.A. Publication office, 200 Madison Avenue, New York.


INDUSTRY PREFERS DIAMOND SOOT BLOWERS
Diamond Power Specialty Corporation, Detroit, Michigan
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Commentary by Joseph H. Keenan

The Education of the Rankine Cycle

Carnot's Principle declares that a reversible heat engine which receives heat at one temperature and rejects heat at a lower temperature will have the maximum efficiency of all possible heat engines working between those two temperature levels. The efficiency of the reversible heat engine is, consequently, the goal toward which we strive in the design of power producing apparatus. But the goal itself is adjustable to the extent that the temperature levels which fix it are adjustable. Of two reversible engines rejecting heat to the same temperature level the one which receives heat at the higher temperature levels will have the higher efficiency.

It is well known that an engine working on the Carnot cycle operates at this maximum efficiency. But we have come to think of the Carnot cycle as a sort of purple cow: we never hope to see one. Its large ratio of compression work to expansion work destroys its efficiency as soon as the practical minimum of irreversibility is introduced. In the Rankine cycle, on the other hand, compression work is only a minute fraction of expansion work, so we resort to it as a practical means of producing work from heat. We cannot object to the Rankine cycle either on the grounds of practicability or reversibility, we can object only to its aspirations. It cannot aspire to the efficiency that a Carnot cycle would realize from its maximum temperature, because it receives much of its heat at temperatures below the maximum. It requires, for instance, that heat be added from the outside source to raise the temperature of cold feedwater up to the boiling point. Try as we might to improve the performance of boilers, turbines and condensers in our Rankine type of plant we cannot overcome the initial handicap imposed by these low temperature heat additions.

The handicap can be lifted provided we can devise a reversible means of heating the power plant fluid which involves no outside heat source except at the highest temperature of the cycle. Such means can be found for a power plant in which dry saturated vapor is supplied to the turbine.

Imagine, for example, a power plant equipped with a turbine which has an infinite number of stages, each of which is entirely free from the usual friction and supersaturation losses. This turbine is supplied with dry saturated steam from a boiler, and it discharges its steam to a condenser which functions without subcooling the condensate. A feed pump is provided which delivers the condensate not to the boiler direct, but to a heating coil placed in the next-to-the-last stage of the turbine. The heat transfer surface provided by the coil is so generous that the condensate leaves the coil at the temperature of the steam in the stage. Next, it is led into a similar coil in the next higher stage in which it is heated to the temperature of that stage, and so it proceeds upward stage by stage until it leaves the highest stage at the temperature of the steam in the main. Since the boiler feedwater is now at the boiling temperature, the boiler functions only as an evaporator and all of the heat transferred from the flue gas is received by the water at one temperature, the boiling temperature.

The reversibility of this cycle can be established without difficulty. Any frictionless turbine can be operated as a compressor if the direction of rotation is reversed. The steam may be condensed at the higher pressure after leaving the compressor by providing a heat sink with a temperature a little below the steam temperature. The condensate may be cooled, instead of heated, in the interstage coils provided only infinitesimal changes in temperature are introduced. It may be expanded through the reversed feed pump and evaporated in the "condenser" if circulating water is provided which is slightly warmer than the cold condensate. The steam produced passes into the turbine to complete the cycle of operations.

Here is a reversible cycle in which heat is received from an outside source at only one temperature level, and that the highest in the cycle; and heat is rejected to an outside sink at only one temperature level, and that the lowest in the cycle. According to Carnot's Principle its efficiency is the maximum that can be attained by any heat engine working between those two temperature levels. It has the high efficiency of the much revered Carnot cycle combined with the low compression work of the Rankine cycle, a combination of qualities which makes it of greater importance to the power engineer than the Carnot cycle itself. It is, in fact, the limiting case of the commonly used extraction cycle.

The power plant engineer must be content with a finite number of turbine stages and a still smaller number of heating stages. He finds it advisable to heat his feedwater in coils placed alongside his turbine instead of within the turbine stage. He has produced, nevertheless, an educated Rankine cycle whose aspirations are nothing short of the performance of a perfect heat engine.

Joseph H. Keenan

Stevens Institute of Technology

EDITORIAL

Too Many Cooks Spoil the Broth

BUSINESS, like government, is prone to overlapping responsibilities which is partly the fault of management and partly the result of human nature and individual ambition. Even in engineering work, which is particularly adaptable to simple and precise procedure, there is a tendency to have too many individuals responsibly involved in particular undertakings. The consequences are loss of time, higher costs and, not infrequently, inferior results.

Engineers, as typical specimens of *homo sapiens*, like to tamper with and change things. Essentially, this is a good characteristic; when used properly, it makes for progress. But if not intelligently used it can hinder the efficient conduct of an undertaking. When a number of individuals are involved in the approval of a single design, the likelihood is that many changes will be proposed which are not necessary and some that are definitely undesirable. One change that may appear to have some advantage will require others that will in turn develop new problems on points that were satisfactorily solved in the original design. Much time is spent in discussion, and inevitably there are compromises. Drawings have to be re-made, delays ensue which later may necessitate undue haste and engineering costs mount.

It seems to us that in respect to these things there is a real analogy between the production of an engineering design and the production of a piece of writing. If a writer is competent, his work, when submitted to those who must pass upon it, should be subjected to change only with respect to meaning and essential limitations of space, purpose, etc. If half a dozen individuals have and exercise the prerogative of making little changes, the result will be a hodge-podge which will have lost that coherence, smoothness and effectiveness which are the natural characteristics of a qualified writer's art.

Broadly speaking the results are the same when an engineering design, which truly reflects the experience and technique of a competent designer, is subjected to the diverse ideas of a group of engineers all of whom share the responsibility of approval.

This condition becomes more serious in connection with large projects—for example, the overall design of a steam generating unit. Here there is much opportunity for difference of opinion on both major questions and details. Long conferences and many of them are necessary before the various diverse opinions can be reconciled. The result is greatly increased engineering cost, loss of time and a final result for which the designer cannot be expected to assume complete responsibility.

Of course a certain amount of this sort of thing is unavoidable, but generally speaking it is greatly overdone. It would be to the real advantage of those who control policy in such matters to review their own procedures from the standpoints of simplicity, efficiency and adequacy.

Better economic results will be obtained if the approval of a design, submitted by a well-qualified designer, is limited to consideration of its conformance to specifications and its general adaptability to conditions of space, performance, etc. Questions of detail design should be left to the designer who may then be held strictly accountable for results.

Progress in Smoke Abatement

AT THE recent annual meeting of the National Smoke Prevention Association, Henry Kreisinger, a leading authority on combustion and related problems, summarized his views in a very interesting talk which concluded the meeting. We quote here in condensed form certain of his comments which indicate the present status of smoke abatement work.

"Smoke abatement has come to mean more than the term implies; it means chimney emission abatement which includes not only the soot particles of which smoke consists but also fly ash and cinders. The meaning of the term is now being extended to include also the removal of sulphur compounds.

"It is fairly easy today to abate or reduce the nuisances of dust, cinders and smoke but we have not yet found an entirely practicable and satisfactory solution to the problem of sulphur removal, although substantial progress is being made in this direction.

"While pulverized coal firing causes the emission of more fly ash than stoker firing, the latter causes more cinder emission.

"The best way to eliminate soot from the flue gases is to burn the coal properly in the furnace.

"Both electrical precipitation and mechanical separation by cyclone are developed to a point where they are capable of removing at least 80 per cent of the dust from the flue gases.

"Standard designs of cyclones will give results that compare very favorably with recent special designs. They will remove over 80 per cent of the dust from gases containing only one-half of a grain of fine dust per cubic foot, with a pressure drop not exceeding three inches and with a fineness of the collected dust such that all of it will pass through a 300-mesh screen.

"Manufacturers of dust collection equipment, if given the opportunity to make more installations, which will give them additional experience, will shortly be able to assure at least 90 per cent separation.

"The cost of dust collecting equipment is not prohibitive. It will range from one or two up to five per cent of the cost of the plant, depending principally on whether it is included in the original design or installed after the plant is built.

"Sampling gases for the determination of dust content, while difficult, can be done to give results accurate within five per cent.

"The handling and disposal of dust offers no insurmountable problems. It is practicable to re-burn cinders containing combustible matter."

These encouraging views from such an authoritative source further confirm the many indications of the past few years that real progress is being made in the important work of eliminating or at least substantially reducing obnoxious emissions from boiler plant stacks. The problem is one that cannot be evaded. Its complete solution will be hastened by a full measure of cooperation between plant engineers and those engaged in the development of the necessary equipment.

Fan Maintenance

By A. R. MUMFORD[1]

The high boiler ratings which are characteristic of modern practice, especially in the larger plants, have made the problem of induced draft fan maintenance an increasingly serious one. The author presents a valuable discussion of this problem based on extensive experience with it in several stations where it has been the subject of considerable study. The accompanying photographs, showing the effects of erosion, and the diagram of dust concentrations are particularly interesting. The discussion covers such points as the characteristics of erosion, the factors which influence it and means of reducing it. The use of alloy steels in parts subject to wear and the application of stellite for purposes of protection and repair are commented upon. The use of dust collectors before the fans is stated to be the only way in which erosion troubles can be eliminated.

LESS than two decades ago Henry Kreisinger and W. T. Ray wrote a report entitled "The Significance of Drafts in Steam Boiler Practice." In this pamphlet the authors pointed out that by artificially increasing the available draft in a steam boiler system, by means of fans, the increased production of steam permitted extensive capital savings. The desirability of reducing capital costs increased in succeeding years and has been responsible for improvements in design of steam generating systems from the ash pit through the furnace, boiler, economizer and air heater to the fan. The fact that some items of operating expense have increased with increased rate of working units is not surprising but the fact that so few have increased and of these few none have increased to a prohibitive amount without immediate and practical design correction is surprising and pleasing.

The maintenance of induced draft fans is one of the debit items chargeable to the economies of modern boiler ratings and capacities in coal-fired boilers. The rates of gas flow have increased from 1500 to 2000 lb. per hr. per sq. ft. of free area to as much as 10,000 lb. with a resultant increase in draft loss. This increase has been made possible by the improvement of furnace design and the introduction of water-cooled walls which permitted the satisfactory burning of greater and greater amounts of coal under the boilers. The pursuit of heat recovery by means of air heaters and economizers changed the fans from the importance of a parallel auxiliary to that of an indispensable part of the steam generating system because of the increased draft requirements.

Forced draft fans handle relatively clean air and their maintenance does not represent anything unusual nor does it introduce new problems. The need of overhauling grows gradually and the necessary repairs and cleaning can be made at the time of regular boiler inspections.

The situation in the case of induced draft fans is different. At the time 200 per cent rating was considered high, the induced draft rarely exceeded 2 in. of water and consequently slow-speed, steel, paddle-wheel fans were entirely satisfactory. The tip speed was moderate and the gas was relatively free of abrasive matter. The increase in the rate of driving the boilers began about 1922 and required higher draft and tip speed. The more rapid flow of gas through all parts of the system caused the retention in suspension in the gas stream of solid particles of fuel and ash. The impact of the solid particles on the rotating and stationary parts of the induced draft fans resulted in erosion and gave trouble. The introduction of rudimentary cinder catchers in the gas stream before it reached the fans helped some but when water was sprayed into the gas, or the gas allowed to impinge on water, the mixture of entrained moisture and suspended dust gave trouble when it attached itself to the fan impellers and casing. Unbalance and vibration were caused by non-uniform loss of weight due to the throwing off of chunks of mud. Moreover the contact of the damp mud with the steel formed conditions most favorable to rapid corrosion. The erosive action of fly ash carried by flue gas was emphasized by the greater draft requirements and higher gas velocities of units from which increased capacity could be obtained by pulverized fuel firing.

[1] Research and Design Engineer, New York Steam Corporation, New York.

In the great majority of steam plants all of the suspended dust in the gases is handled by the induced draft fans but there are a few boiler installations in which dust catchers are installed before the fans. Fifty to ninety per cent of the ash in the coal leaves the boiler suspended in the gas stream. As an average it seems fair to say that 60 per cent of the total ash passes into the fans. This fly ash will have more or less pronounced abrasive properties depending upon the properties of the ash and the furnace temperature. Fly ash from boilers fired by lignite, for example, shows a flary composition, is very soft, and is not abrasive. The abrasive action of fly ash is roughly proportional to the silica content for the harder coals but other constituents such as unburned coke and pyrites also become abrasive at high gas velocities and tip speeds. The importance of erosion troubles may be judged from the fact that in certain installations a new set of fan blades would be reduced to scrap metal within three weeks if precautions were not taken. Thus far no means, other than the installation of dust catchers before the fans, have been found to eliminate this trouble entirely, but various practical measures are being taken to prolong the life of fan blades and casing. These remedial measures will be discussed in the following paragraphs.

Characteristics of Erosion

It is obvious that the wear will be proportional to the relative velocity and to the dust concentration for a fly ash of given properties. The relative velocity is a function of the fan duty but the concentration varies capriciously depending upon the path of the gases, time elapse after a velocity change, and the rate of combustion. Cyclonic action in the fan is sufficiently powerful to highly concentrate the gas at the points of greatest velocity and direction change. A. E. Zingone traversed a single inlet fan and by means of dust collecting and gas metering devices found variations in dust concentrations as shown in Fig. 1. These diagrams indicate the degree to which dust may be concentrated in a fan. In each diagram the average concentration for the particular traverse is shown by the dotted line. That a single inlet fan causes asymmetrical dust distribution is clearly shown. The gas may be pictured as entering the wheel through the inlet at a fanned-out angle, being whirled

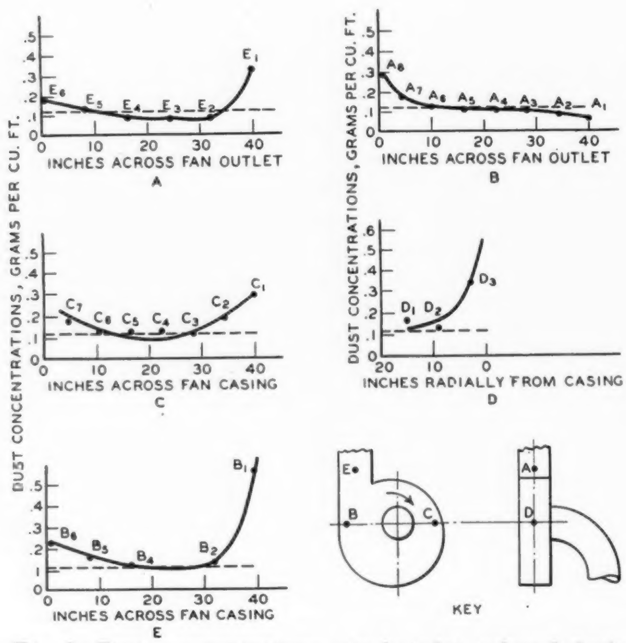


Fig. 1—Dust concentrations, single inlet induced draft fan, based on data obtained by A. E. Zingone

and circulated in the wheel during the period of radical acceleration, and leaving the field of circulation at some angle, roughly 90 deg. to the axis of entry. This twist component is therefore responsible for the asymmetry of dust distribution. In studying these curves it should be borne in mind that the dust concentration on the wearing surfaces is many times greater than in the next layer of gas because of the quick precipitation of the denser and larger particles which are missed in the gas samples. The normal deduction that the erosion will be greater on the side opposite the inlet is amply supported by actual observations. In a double inlet fan the sides of the casing

Fig. 2—Typical wear on side casing opposite inlet

suffer less but the erosion will be concentrated in the middle of the rotor.

Fig. 2 shows the typical wear on the side of the casing which is opposite the inlet.

Fig. 3 shows the asymmetrical wheel wear in the same single inlet fan.

The symmetry of gas flow is restored in the double inlet fan resulting in the concentration of dust toward the center of the wheel. Fig. 4 shows the channeling and grooving of the division plate and the concentration of erosion at the junction of the blades and division plate. This photograph represents the action of cinders from a stoker-fired furnace but it is a fair representation also of conditions with powdered coal firing.

Several interesting methods have been developed to decrease outage caused by this distinct type of fan erosion. Wear of the side casing is usually repaired by patch welding. In Fig. 3 it may be noted that the fan blade itself has been constructed of two parts for the purpose of allowing low-cost boiler plate replacements in the area subject to concentrated wear. It may also be noted that most of the blade area shown is relatively unaffected. In addition to dividing the blade it may be noted that a corner reinforcing angle has been welded to the shroud and faced with stellite. The results obtained with stellite are good, if the stellite has been properly applied. Fig. 5 shows how the wear pictured in Fig. 4 was resisted by the installation of triangular wear blocks which, as may be noted, have the wearing edges protected by stellite. The area of these blocks would probably not increase the wearing surface sufficiently to materially delay outages under the severe conditions of powdered coal firing.

Normal wear must be expected on the spider arms and hub. It is possible to replace the eroded metal with welded patches but the particular conditions of service under which the fan operates must determine the advisability of this. Fans fitted with inlet vane control have been found, in certain installations, to have a more uniform distribution of the gas by the vanes which thus tends to distribute the wear more evenly. The vanes themselves, however, are worn in the process of distributing the dust laden gas so that protection of their leading edges by some such material as stellite is necessary to prolong their useful life. The uniform distribution of wear postpones the maintenance expense but the cost may be great when repairs are made. Under the pressure of high production demand, it is necessary to quickly and accurately appraise the extent of the damage by erosion and to determine the steps necessary to the early resumption of safe operation. This appraisal can be more quickly made when the erosion is highly localized than when it is uniformly distributed.

The fact that the maintenance methods discussed thus far make of the fan a sort of crazy quilt patch work is evidence only of the endeavor to compromise between the present prohibitive cost of a fan designed and built to withstand the expected and unexpected erosion and the inadequacies of standard designs of fans for particular operating conditions. Moreover although the erosion in each instance will follow the general characteristics described it will necessarily differ in intensity and location for each installation. The amount of maintenance to be encountered will vary with a number of factors, such as tip speed, average dust content of gas, concentrating action of fan, gas temperature, abrasive properties of the dust, and path of the gases and turbulence before the fan inlet in so far as they influence dust distribution, etc. All of these factors cannot be evaluated on the basis of present experience, and it is necessary to operate an installation for some time before the results become known.

Economy dictates the selection of a moderately heavy fan so designed that it can be reinforced when the points of wear have been located by a trial run. In one large central station, known for its careful design and excellent operation, the induced draft fans were located with emphasis on the ease of access and rapid convenient handling of rotors. After testing, the rotors were fitted with half-inch wearing plates on the blades. Several

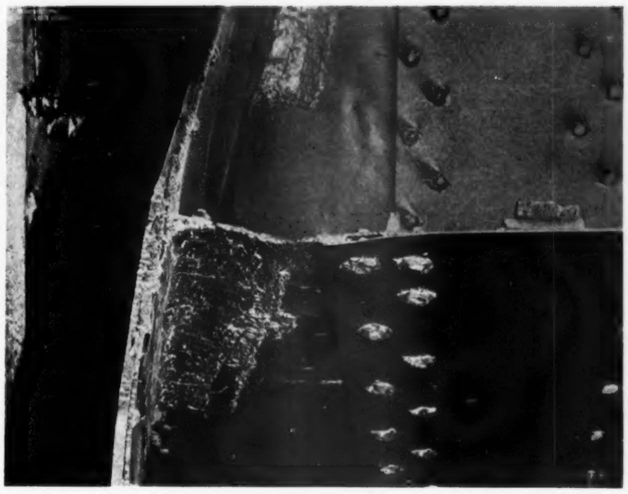


Fig. 3—Asymmetrical erosion of fan blade, single inlet fan

kinds of steel for these plates are now under investigation. Good performance is considered to be four to six months service with high sulphur mid-west coals.

The idea of covering the blading with wear-resisting material, which would also have the necessary properties to enable it to withstand the temperature, is very attractive, and many experiments have been made. Rubber, bakelite, glass, cast iron, wrought iron, hard alloy steels have all been tried with indifferent results. The economical solution to the problem seems to consist of the application of stellite-protected pieces of steel to the spots of concentrated erosion and a construction which allows the easy replacement of worn parts with the least waste of material.

The complete solution of the erosion problem is the highest possible reduction of dust concentration in the gas before it reaches the fan by the installation of dust catchers ahead of the fan. Gas washers should be effective in reducing dust concentration but must be followed by reheating of the gas if protection against rapid corrosion is to be insured. Dry collectors of the electro-static or cyclonic types should reduce the erosion greatly. The greatest erosion is probably caused by the coarser and denser particles which, because of their momentum, resist changes in direction more successfully and if these are removed the remaining fine dust is likely to remain more evenly distributed and consequently be less harmful. It is unfortunate that dust eliminators are usually installed as a later addition because of the desire to eliminate a nuisance and thus do not constitute an integral part of the original draft system in which case they could be installed in a position that would assure protection to the fans.

Fig. 4—Erosion at division plate of double inlet fan

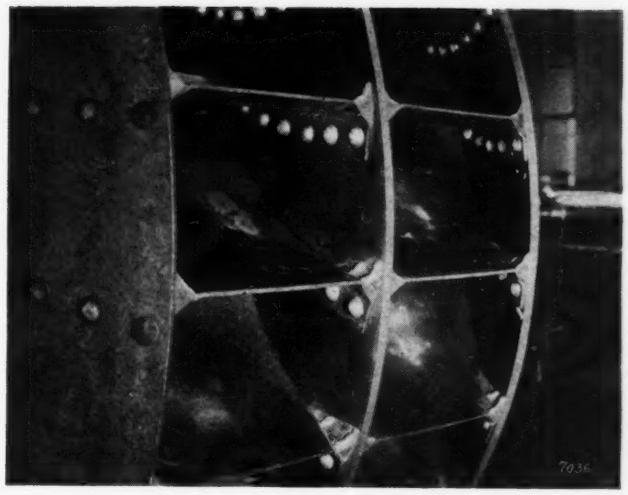


Fig. 5—View showing wear resisting blocks as installed on double inlet fan

Casing Wear

The scroll and the edges of the side casing are surfaces subject to severe abrasion because the greatest dust concentration must exist at these points. Curve D of Fig. 1 indicates the relative corrosion in the plane of the rotor. Sectional cast-iron casing liners are now universally used to delay and simplify maintenance at these points. The danger of exposing the supports of these liners to abrasion after the protection afforded by the liner is lost through wear makes it essential that these liners be periodically and regularly inspected. Sufficient erosion of the support will drop the liner into the wheel with disastrous results.

Mr. James D. O'Brien in charge of Stations K, B and A of the New York Steam Corporation has patented an improvement on the ordinary type of scroll and casing liner which has considerably extended the life of the liners. The improved liner consists of cast-iron sections the faces of which are given a saw tooth serration as shown in Fig. 6. The sections are installed so that the teeth "bite" against the gas flow, and thus allow the serrations to become filled with dust so that the larger part of the surface is protected by dust. It is obvious that any abraded dust is instantly replenished. These liners have an indicated life twice that of the ordinary liner.

Alloy Steels and Stelliting

The economic and practical aspects of the substitution of alloy steel for boiler plate in fan blades are both difficult. The stresses at high tip speeds require high tensile strength and toughness which does not usually accompany the hardness characteristic of abrasion resistance. Ordinary alloy steels do not offer any advantage because their maximum hardness obtainable with reasonable toughness will be low and the gain in endurance would be expensive. The properties and heat treatment of an alloy steel should be carefully investigated before its installation. It seems advisable, at this time, to look for an armoring alloy steel and protective angles, small

Fig. 6—View showing sectional serrated cast-iron scroll liners

plates, liners and nuts of hard alloys rather than an entire rotor of the necessarily softer alloy. The alloy steel armoring should be securely applied to moving parts preferably by welding if the alloy permits it. The judicious application of stellite to spots of extreme wear has proved economical inasmuch as the life of the part has been at least doubled and the application lends itself readily to the building up of worn spots.

General

The skyscraper idea seems to be adopted for boiler unit design inasmuch as a furnace is placed on an ash pit, a boiler on that, then an economizer and an air heater. The logical place for the induced draft fans is at the top where, unfortunately, any tendency to unbalance has a column on which to work which emphasizes the condition. The proper use of steel and concrete in the fan foundations must be supplemented by quick detection of and rapid remedial applications to any unbalance. The combination of variable thermal expansion, unbalance, occasional unbalanced thrusts, frequent vibration, and of many other factors places the induced draft fans in the class of heavy duty auxiliaries and a rather high mechanical maintenance is to be expected as compared with service pumps of air compressors.

Mill exhausters, handling air laden with powdered coal, face conditions of wear by erosion much the same as induced draft fans. That the coal dust is abrasive is evidenced by the using up of about a half pound of steel per ton of coal ground in the mills and it is to be expected, therefore, that the exhausters which handle the dust at high speed must also lose weight. The maintenance of mill exhausters installed between the mill and the cyclone is similar in character and extent to that of induced draft fans.

The maintenance cost of forced draft fans is occasional and negligible.

The maintenance cost of induced draft fans varies with the type of fan, tip speed, type of firing, coal, etc., and will be different for each installation. Costs varying from one mill to one cent per ton of coal burned have been reported by stations using the same general type of equipment and consequently even a well averaged figure would be meaningless as a guide for any particular case.

Robert Lindsay, President and General Manager of the Cleveland Electric Illuminating Company, died at his home in University, Virginia, on August 25th. Mr. Lindsay was a Director of the North American Company, a member of the Edison pioneers and of numerous business organizations in Cleveland. He had been in poor health for a year prior to his death.

Combustion Engineering Reorganized

As of August 1, 1933, Combustion Engineering Company, Inc., a newly organized company, took over the properties of International Combustion Engineering Corporation and affiliated companies recently sold by order of the Federal Court. The properties acquired include those of Combustion Engineering Corporation, Hedges-Walsh-Weidner Company, Coshocton Iron Company and Raymond Bros. Impact Pulverizer Company. In order to assure the best possible service to the company's customers, these properties will be operated under a single centralized management.

The new company will continue Combustion Engineering Corporation's complete line of fuel burning, steam generating and related equipment which includes all types of stokers, pulverized fuel systems and boilers, as well as water-cooled furnaces, economizers, air preheaters, ash conveyers and hoppers.

The same engineering personnel and manufacturing facilities which, in the past, have enabled the company to carry out many of the most notable engineering projects in its field, will be continued by the new organization. The company's principal lines of equipment will be available in a range of sizes adequate for plants ranging from about 50 boiler horsepower up to the largest built.

The officers of the new organization are: Frederic A. Schaff, President; Joseph V. Santry, Executive Vice-President; Robert M. Gates, Vice-President in Charge of Sales; Martens H. Isenberg, Vice-President in Charge of Production; John Van Brunt, Vice-President in Charge of Engineering; Harold H. Berry, Treasurer; George W. Grove, Secretary and Assistant Treasurer; George D. Ellis, Comptroller.

The American Standards Association announces the appointment of a new subcommittee on Nomenclature of the Sectional Committee on Classification of Coal (M20). The subcommittee, appointed by A. C. Fieldner, chairman of the sectional committee, is as follows:

E. A. Holbrook, dean, School of Engineering, School of Mines, University of Pittsburgh, Pittsburgh, Pa., Chairman.

G. H. Ashley, state geologist, Topographical and Geological Survey Commission, Harrisburg, Pa.

H. N. Eavenson, president, Clover Splint Company, Pittsburgh, Pa.

W. H. Fulweiler, chemical engineer, United Gas Improvement Company, Philadelphia, Pa.

T. W. Harris, Jr., division purchasing agent, E. I. du Pont de Nemours & Company, Wilmington, Del.

T. A. Hendricks, assistant geologist, U. S. Geological Survey, Washington, D. C.

M. M. Leighton, state geologist, State Geological Survey, Urbana, Ill.

H. J. Rose, Senior Industrial Fellow, Mellon Institute, Pittsburgh, Pa.

E. Stansfield, University of Alberta, Edmonton, Alberta.

F. R. Wadleigh, Cape May Point, N. J.

The sectional committee is under the sponsorship of the American Society for Testing Materials.

The scope of the work of the new subcommittee will include names for the groups, classes, and subclasses of coal according to rank and type. Although the literature of coal technology, including the reports of the previous work of this sectional committee, contains names that have been customarily applied to coals of various types, it is understood that this new technical committee will present recommendations based upon its own investigations.

A Critical Study of Boiler Scales and Advanced Methods of Analyses and Identification

By SHEPPARD T. POWELL
Consulting Chemical Engineer
Baltimore, Maryland

In this, the third article of Mr. Powell's series, a very thorough discussion of scale formation is presented. Emphasis is placed on the importance of extended research to meet the new problems introduced by present-day design and operating practice, the solution of which requires improved methods of analysis and treatment. The principal part of the article is devoted to methods of scale analysis. Chemical methods, while having certain value, are not adequate, especially with respect to high-pressure boilers, in that they do not permit of accurate identification and structural study of crystalline deposits. Petrographic analysis, as used in the microscopic study of rocks, appears to be a satisfactory technique. . . . The effect of scale deposits on heat transfer is discussed, the conclusions offered indicating that the losses are not as serious as is generally thought. . . . Details are given of several studies of complex scale deposits which caused serious difficulties.

THE formation of scale on heating surfaces of boilers has always been a troublesome operating problem in steam generation. The magnitude of scale formation and the resultant difficulties vary with local conditions and are greatly affected by temperatures, pressures and ratings at which the generating equipment is operated. In small stations operating at low rates of evaporation and at moderate temperatures and pressures, the formation of scale is not a critical condition and its removal, although troublesome, is generally not an insurmountable task. The decided trend in recent years toward higher boiler pressures and temperatures has, however, introduced many new factors and makes the control of scale an engineering problem of major importance from the standpoint of reliability and continuity of boiler service.

To those whose experience has been limited to the operation of low-pressure stations, the significance of the situation may not be readily apparent; consequently opinions within the engineering profession as to the importance of the problem differ materially. This has been aptly pointed out by one observer* who states, "This cleavage of opinion is, broadly speaking, a matter of past and present."

* "The Formation of Scale," Editorial in *Engineering*, January 30, 1931.

To thoughtful and experienced designers and operators, it is clearly apparent that the advancement of the last few years in the design of steam generating equipment has brought with it many new problems of water conditioning which are not completely solvable by current knowledge. Recent experiences of many operators tend to confirm this opinion and have directed attention to the desirability of future research on the subject. In the past, the effort toward scale prevention has been largely in the hands of groups interested commercially in the sale of equipment or scale prevention processes, and relatively little time or effort has been devoted to fundamental research concerning the mechanism of scale formation. Further advance toward a solution of this troublesome problem must develop through such research with due consideration of the inadequacy of current procedure to cope with the difficulties. The problem is not one merely of stoichiometry chemistry, but involves an intimate knowledge of crystallography and thermodynamics and the influence of temperatures, pressures and solubility coefficients of complex solutions on crystal formation. This in turn requires complete revision of stereotype analytical procedure, essential improvement in the accuracy of existing sampling technique, critical study and interpretation of heat transfer rates through metals and other influencing factors. A few investigators have undertaken comprehensive studies along these lines and although the results obtained are by no means complete, they have served a most useful purpose in directing attention to the necessity for future study in this field.

The deposition of scales on boiler heating surfaces is primarily a question of the solubility of salts at elevated temperatures. There are much data in the literature concerning the solubility of calcium and magnesium and other compounds normally present in water, but the majority of these data relate to solubilities in pure solutions and at relatively moderate temperatures. It is only within recent years that such investigations have been extended to include solubility data of mixed salts in aqueous solutions and at temperatures and pressures comparable with contemporary practice in high pressure steam generating stations.† Much credit is due to R. E. Hall[1] and his associates for fundamental data on this subject. Possibly the most comprehensive research study concerning the mechanism of scale formation was that carried on at the University of Michigan in 1930 under the direction of Everett P. Partridge.[2] This theory, which has been fairly well proved in actual practice, is stated tersely by Partridge as follows:

"Scale deposition and growth on the heating surfaces of boilers is due chiefly to the fact that certain slightly soluble substances become less soluble with increase in temperature. Some initial deposition of scale crystals by sedimentation, or by trapping in surface irregularities may take place in boilers

† Extensive solubility studies are now being made at the University of Illinois under the direction of Professor Frederick G. Straub.

[1] "A Physico-Chemical Study of Scale Formation and Boiler-Water Conditioning," by R. E. Hall and others, Bulletin 24, Mining and Metallurgical Investigations, Carnegie Institute of Technology, Pittsburgh, Pa.

[2] E. P. Partridge, "Formation and Properties of Boiler Scale," Dept. of Engineering Research, University of Michigan, No. 15, 1930.

of the horizontal return tubular or marine types, but it is probable that scale formation in the tubes of water-tube boilers is due to an entirely different action.

"The initial deposition of scale crystals is generally the result of crystallization at the boiler surface from a solution which is supersaturated with respect to the scale-forming substance. The whole body of a boiler solution constantly tends toward a state of supersaturation as steam is removed; in addition, since scale-forming substances decrease in solubility with increase in temperature, the film of boiler water adjacent to a heating surface tends to be supersaturated even when the body of the solution is only at the saturation point. Supersaturation in the liquid film at the heating surface may be relieved by spontaneous crystallization, possibly promoted by irregularities in the surface, even when no vaporization is taking place. When bubbles are being evolved at the heating surface, however, the excess solute is deposited in minute crystals in rings directly at the solid-liquid-vapor interfaces formed by the metal surface, the boiler water and the bubbles forming in contact with the surface. This latter action undoubtedly accounts for the deposition of practically all of the initial scale nuclei on boiler surfaces at which actual vaporization of water is taking place.

"The growth of scale following initial deposition of crystal nuclei may proceed in either of two ways. The existing crystals may grow by contact with the supersaturated liquid film with which they are continuously in contact. If these crystals are removed from contact with the solution, as by the absorption of a film of a colloidal substance present in the boiler water, further deposition of new crystals superimposed on the previous deposit may take place as the result of bubble evolution. In the first case the resulting scale will consist chiefly of relatively large continuous crystals orientated more or less perpendicularly to the heating surface; in the second case, the scale will consist of relatively small crystals with a random orientation."

A similar theory was earlier advanced by Sir John Dewrance[3] to account for the corrosion phenomena from hydrochloric acid generated by the deposition of magnesium chloride on heating surfaces and has been confirmed by the writer in numerous studies of scale growth in boilers. The growth of such deposits is undoubtedly accelerated by the effect of skin friction at the surface of the tubes, since the velocities along the tube wall are much less than toward the center of the tubes. This latter phase in the mechanism of scale growth has not been studied by investigators but the writer's recent experiences would indicate that it has a marked accelerating effect and accounts for the deposition of many forms of silicate scale which might not otherwise develop in the presence of very small amounts of siliceous materials present in the feedwater.

Effect of Scale upon the Rate of Heat Transfer through Metal

Many investigators have reported the heat conductivity coefficients of boiler scales, but there is wide variation in these data. It is a recognized fact that boiler scales are relatively poor heat conductors and when deposited on metal surfaces may result in a marked reduction of boiler efficiency. Such losses are influenced by the physical character of the deposits, the design and operation of the boiler and many other factors. Actually, however, these losses are not nearly as great as was originally supposed. Schmidt and Snodgrass[4] in their widely quoted report stated:

"1. Loss in rate of heat transmission due to scale might vary from insignificant amounts to as much as 10 or 12 per cent.

"2. The amount of the loss increased somewhat with the thickness of the scale.

"3. The mechanical structure of the scale had an influence as great as, or greater than the thickness of the scale in causing heat (conductivity) loss.

"4. Chemical composition, except as it affected the physical structure of the scale, had no direct influence on the rate of heat transmission."

These findings, however, referred merely to reduction in rate of heat transfer due to scale deposits and are not to be confused with reductions in boiler efficiencies resulting from scale only. Stromeyer,[5] Risteen,[6] Reutlinger,[7] and more recently Partridge[8] have demonstrated that the importance of boiler scales in the reducing of boiler efficiency is generally over estimated and frequently exaggerated. As early as 1909, Eberle[9] concluded that:

"From the results of the experiments it is to be concluded that a scale deposit averaging 5.5 mm. in thickness and of average heat conductivity, influences the heat utilization in a boiler but very little, so that the determination of this influence in a reliable manner by comparative boiler tests is not possible."

Partridge[8] has likewise drawn the same conclusion and states:

"The calculated effect of the formation upon the whole area of a boiler heating surface of 0.1 in. of scale with a heat-conductivity coefficient of 1.0 B.t.u. per sq. ft. per deg. fahr. would be to decrease the overall heat conductivity 7.69 per cent. This decrease in heat conductivity would not, however, cause a proportional decrease in heat utilization. For a boiler operating at a gage pressure of 150 lb. per sq. in. and assumed furnace and waste gas temperatures of 2500 fahr. and 600 fahr. respectively, the decrease of 7.69 per cent in the overall conductivity of the heating surface produced by the specified scale deposit will cause a decrease in the efficiency of heat utilization by the boiler of less than 2 per cent."

Although material loss in heat utilization in boilers probably does not generally occur from scale accumulation, still such deposits are highly objectionable on account of the elevation in tube temperatures resulting from their insulating effect. This condition is especially noticeable in the first few tubes above the furnace. Rates of total heat input up to 100,000 B.t.u. per sq. ft. per hr. in modern boilers may be required and heat input rates of the magnitude of 70,000 to 80,000 B.t.u. per sq. ft. per hr. are not unusual. To meet these critical conditions, clean tube surfaces are required since the relatively low heat conductance of both porous and non-porous scales will cause rapid elevation of the tube temperatures beyond the yield-point of the metal even when the deposits are only a few millimeters in thickness. Partridge has calculated that:

"Rate of heat transfer by radiation of 75,000 B.t.u. per sq. ft. per hr. or over have been estimated for front-row and water-wall tubes in contemporary installations. With such high rates, deposits of non-porous scales of the order of thickness of 0.05–0.10 in. will cause failure of tubes by overheating, while extremely porous scales of one-tenth the thickness may produce the same result. Since increase in boiler pressure decreases the allowable margin of elevation in the tube temperature, the problem of scale prevention will become continually more important as boiler pressures and ratings increase."

The writer's experience confirms the above estimates and tube losses from silicate (porous) scales have been noted when the average thickness of the deposit was approximately 0.3 mm., or 0.012 in. in thickness.

Analysis of Boiler Deposit

Determining the composition of boiler scales by quantitative chemical analyses has always been, and still is, widely practiced. Such analytical procedure serves a useful purpose for determining the type and quantity of various constituents

[3] Sir John Dewrance, "Corrosion of Boilers," *Power*, March 29, 1921. "Boiler Feed Water Purification," by S. T. Powell, McGraw-Hill Book Company, 1927.
[4] Schmidt and Snodgrass, University of Illinois, Engineering Experiment Sta. Bull. 11 (1907).
[5] Stromeyer and Baron, *Proc. Instit. Mech. Eng.* (1903), 772.
[6] Risteen, *Locomotive*, 23, 129 (1902).
[7] Dr. E. Retlinger, Bavarian Research Society, 1910.
[8] Everett P. Partridge, "Formation and Properties of Boiler Scale," Dept. of Eng. Res. University of Michigan, No. 15 (1930).
[9] Eberle, *Z. Bayer, Rev.*, Verein 13 (1909).

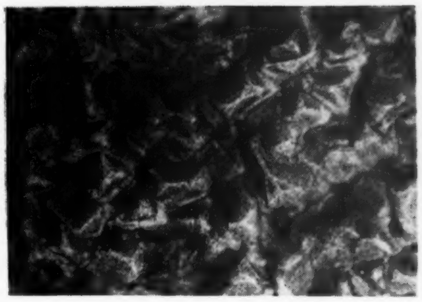


Figure 1
Microphotograph of analcite scale showing cubic faces modified by trapezohedrons. Magnification 100 dia.

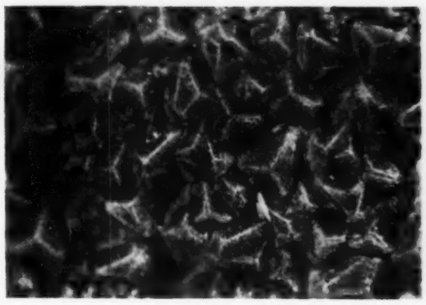


Figure 2
Microphotograph of analcite scale showing dominant trapezohedral faces. Magnification 100 dia.

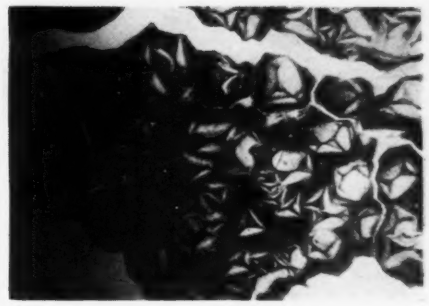


Figure 3
Photograph of a thin section of analcite scale parallel to surface of deposition of scale showing orientation of sub-microscopic impurities at intersection of crystallographic planes. Magnification 100 dia.

present in the deposits under examination but, beyond this, little accurate information is to be gained by such an analysis. It is frequently impossible, from these data only, to determine the density or porosity of the deposits, the exact mineralogical classification of the material, or any other essential information relating to its formation, structure or physical properties. Such analyses are merely arbitrary mathematical combinations of the specific elements recorded. They may or may not indicate the specific material deposited, depending upon chance and the intelligence and experience of the observer. Such analytical reporting, unless confirmed by physical, microscopic or crystallographic examination, will give little specific information concerning crystal formation of the specific material or variation of crystal growth of one type of deposit upon another. Chemical analyses of boiler scales are useful, primarily, for determining the presence of various elements or as supplemental to other physical or petrographic data. Beyond this, such analytical procedure is of little value.

Recently, three samples of the same scale deposits were submitted to three chemists for analysis. There was complete disagreement as to the character of the scale and none was able to identify the material accurately. The reason for this wide diversity of opinion was due to the fact that the scale submitted was, in reality, a double crystal formation consisting of calcite crystal and crystals of calcium-magnesium phosphate and carbonate, presumably species resembling collophane or dahllite. According to Rogers:[10]

"Collophane is amorphous calcium carbonophosphate. This mineral bears the same relation to crystalline dahllite ($3Ca_3P_2O_8.CaCO_3$) that opal does to chalcedony or quartz. Collophane, however, contains a small amount of calcium fluoride. Actually collophane may be regarded as a solid solution of calcium carbonate, calcium fluoride, calcium sulphate and water in tricalcium phosphate. Dahllite as occurring in nature is closely associated with collophane.

"Concerning the conditions which bring about the formation of these deposits in engineering practice, future data are needed. These should include accurate analysis of the feedwater used and crystallographic studies of the compounds formed. With such data available the control of scale formation will be indicated."

The error in failure to identify this and many other scales by chemical analysis is in no way a reflection on the ability or integrity of the analysts in question but demonstrates the inherent inadequacy of chemical analytical procedures as a reliable differential method for identification of complex crystalline deposits occurring in high-pressure boilers.

Silicate scales are particularly troublesome and their control and elimination is frequently difficult. Probably there are no constituents in water which are so little understood as silica. Little accurate scientific data have been acquired concerning the behavior of siliceous compounds in water at high temperatures and pressures, although the need for such data is becoming increasingly important.

It is commonly supposed that when silica deposits as boiler scale it is generally in the form of calcium silicate or magnesium silicate and these silicates undoubtedly do occur. There is no certainty, however, that silicate deposits are always of this type. Recently, other silicates have been identified which indicates that many forms of silicates may occur under critical boiler operating conditions.

A recent comprehensive study of silicate scale showed the deposit to be analcite, a type of scale which, to the writer's knowledge, has not been previously identified by other investigators. This form of scale is highly interesting, since it has a relatively low coefficient of heat conductance and may form when the feedwater contains only a few parts per million of silica.

Petrographic Study of Boiler Scales

Petrography is the systematic and descriptive side of the study of rocks. The identification of boiler scales by means of the petrographic microscope may be accomplished by study and observation of the minerals in thin sections or by the immersion method. Larsen[11] advocates identification of minerals by immersion in preference to investigations of thin sections.

The immersion method consists of immersing the powdered mineral in a liquid medium whose indices of refraction are known and determining it's optical constant. Larsen[11] in 1921 prepared a set of tables for systematic determination of minerals from their optical constants and set forth the optical constants for more than 500 species for which data were not previously available. In discussing this microscopic procedure he stated:

"The science of mineralogy needs also good connected and consistent data on minerals. Chemical analyses, crystallographic studies and determination of physical properties, optical constants, and paragenesis should be made on identical materials. Greater care should be taken in examining minerals for lack of homogeneity whether it is due to zonal growths or to admixture or included foreign material. The optical method might be used with advantage in work done in a number of branches of science other than mineralogy and in some industries. It should be much more generally used in chemistry, especially in analyses of artificial crystalline products to determine rapidly the exact nature of the material and its homogeneity, for artificial products have a definite optical constant as minerals."

This suggestion has particular application in studies of boiler scales owing to the marked similarity of these synthetic forms and minerals occurring in nature. The identification of

[10] A. F. Rogers, "Collophane—A much neglected mineral," *American Journal of Science* No. 16, 1922, pp. 269-276.

[11] Esper S. Larsen, "Microscopic Determination of the Non-opaque Minerals," U. S. Geological Survey Bulletin 629.

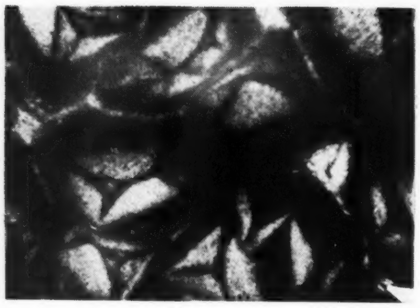


Figure 4
Microphotograph of the thin section of analcite scale shown in Fig. 3. Magnification 250 dia.

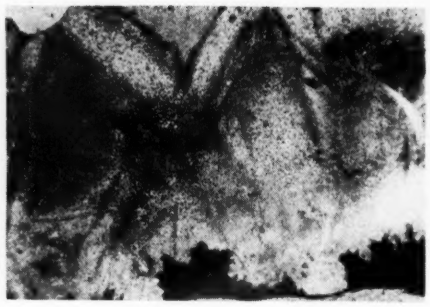


Figure 5
Microphotograph of thin section of mud drum deposit, transverse to surface of deposition showing contact of ferruginous and analcite components of the deposit. Magnification 100 dia.

Figure 6
Crystals of dendritic copper identified in mud drum deposit. Magnification 35 dia

the structure and growth development of boiler scale by petrographic methods has special merit, since it not only makes possible the accurate determination of substances deposited but reveals the presence of concurrent deposits and contaminating material occurring or crystallized simultaneously with the major crystal formation. By correlation of such crystal growth with boiler water conditioning and operation data, procedure for inhibiting scale deposits may be developed.

With the exception of the sulphate, carbonate and hydroxide of calcium and magnesium there is little definite crystallographic data concerning various complex forms of boiler scales. Calcium carbonate is almost always present as calcite, calcium sulphate as anhydrite and magnesium hydroxides as burcite. These forms may readily be identified by petrographic analyses. Many of the more complex deposits, especially silicates, require broad experience and adequate microscopic equipment for accurate identification.

Typical Scales Identified by Petrographic Analyses

A number of scales and miscellaneous deposits occurring in boiler pipelines and feed pumps have been observed recently in studies of difficult scale problems. The microphotographic records have revealed many crystal structures of unusual interest. Some of these are reproduced here to illustrate the potential value of such studies as a control procedure to indicate the solution for inhibiting difficult boiler scale and turbine blade deposits.

An interesting deposit was removed recently from the turbine blades of a high-pressure boiler feedwater pump, supplied with lime-soda softened water. The scale was dark brown and laminated, extremely hard and porous. Approximately 60 per cent was calcium carbonate. It was definitely identified as calcite with inclusion of organic matter and colloidal silicate in the form of "opal." The high porosity of this type of scale and the presence of silica, although relatively small in amount, resulted in much difficulty.

Considerable tube difficulty was experienced from scale formation which resulted in the loss of many tubes within one month's operation. The feedwater from which this scale deposited was treated by a hot lime-soda system, ferrous sulphate being employed as supplementary treatment. The boilers were operated at 400 lb. pressure. The deposits were identified as calcite and anhydrite with small inclusions of opal. The laminated structure of the deposit clearly indicated over and under treatment of the feedwater. The tube losses were due, not so much to the composition and porosity of the scale, as to loose bonding to the tubes permitting steam blanket of the metal in restricted areas with resulting poor rate of heat transfer and localized over heating.

The most interesting scales identified by petrographic analyses were those composed largely of analcite. This silicate is one of the zeolite groups having many interesting properties. According to C. Doelter[12] analcite ($Na_2O.Al_2O_3.SiO_2$) will form whenever the components exist in a closed system between temperatures of 180 cent. and 430 cent. (350 to 800 fahr.). The temperature of the boiler water from which this scale deposit was taken was 550 fahr., but the temperature of the tube surface was not known. Above the upper temperature limit of 430 cent., analcite is said to pass into an anhydrous compound (Nepheline) of the formula $Na_2O.Al_2O_3.2SiO_2$. Below the lower limit of 180 cent. analcite passes into Natrolite another zeolite $2H_2O.Na_2O.Al_2O_3.3SiO_2$.

Analcite is not a rare mineral in regions of volcanic rocks. It is frequently found in fissures and cavities in lava, often in fine crystals. Its origin is in the hot aqueous solution that marks the final phase of volcanic activities after the magmatic

[12] C. Doelter, *Mineralogische und Petrographische Mittellungen*, Vol. 25, 111, 1906.

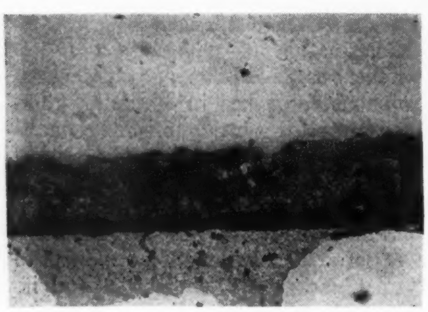


Figure 7
Microphotograph of deposits of anhydrite and calcite showing line of demarcation between scale and graphite paint on boiler surfaces. Magnification 100 dia.

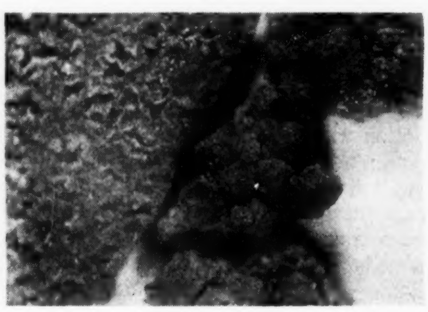


Figure 8
Microphotograph of analcite fragments from mud drum deposits. The grain in the center is much more crystallized than the others. Each of the six or seven knobs is a separate crystal. Magnification 35 dia.

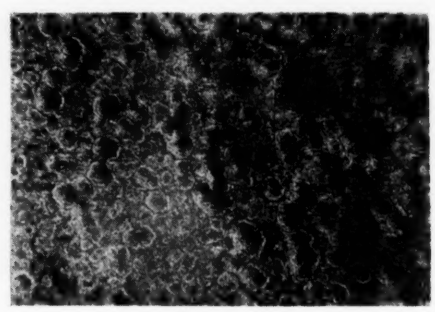


Figure 9
Microphotograph of phosphate scale. Section parallel to bedding of deposit. Impurities regularly distributed outlining the internal structure. Magnification 100 dia.

solutions have reached a moderate temperature and pressure. Artificially, analcite has been made in various ways as heating sodium hydroxide or silicate in a sealed aluminum glass tube at 180 to 190 cent. for 18 hr.[13] A. de Schulten[14] prepared synthetic analcite by mixing solutions of sodium silicate and sodium aluminate in such proportions that the alumina and silica were the same as in analcite, adding a suitable amount of lime water, and heating in a sealed copper tube at 180 cent. After 18 hr. he obtained crystals of analcite of the following compositions:

	Artificial Analcite	Natural Analcite
Silica	55.4%	54.4%
Alumina	22.1	23.3
Soda (difference)	14.3	14.1
Water	8.2	8.2
	100.0	100.0

It is to be noted that the lime water has no other function than to facilitate the crystallization.

Viewed through a microscope the surface of analcite is seen to consist entirely of well defined faces, showing typical cubes and trapezohedrons. These conditions are illustrated in Figs. 1 and 2. According to Dr. Charles Milton,[15] "when the solution is very concentrated and alkaline, the crystals form trapezohedrons, under other conditions cubes." Other photographs of thin sections of these interesting scales are shown in Figs. 3 and 4.

Figure 10

Microphotograph of the upper surface of phosphate deposit from mud drum. Magnification 100 dia.

It is seldom that a single deposition of crystals will occur and boiler deposits as a rule are conglomerated mixtures but with one or more substances predominating. This condition is shown in the microphotograph of a mud drum deposit reproduced in Fig. 5. This deposit is composed largely of ferric oxide and hydroxide with characteristic crystals of pure analcite, also a few crystals of metal copper and small amounts of other occluded material.

Several growths of dendritic copper crystals were found in the deposit, the presence of which had previously been determined by chemical analysis to the amount of 2.5 per cent of copper oxide. A reproduction of these copper crystals is shown in Fig. 6. It was believed that the crystals of metal copper were due to the reduction of copper salts in the boiler water salines which were reduced to a metallic state under the influence of boiler conditions. The only apparent explanation for the presence of copper salts in the water was from the corrosion of brass fittings. It is conceivable that in contact with the iron surfaces of the boiler, electrochemical deposition could occur with the deposition of metallic copper with an equivalent solution of iron.

In Table I is given the results of analyses of a dense scale laid down on the drums and tubes of a 400 lb. pressure boiler, the feedwater for which is softened with intermittent cold lime-soda treatment. This scale accumulated slowly and has caused no serious inconvenience. The deposit is essentially calcite with small amounts of analcite and anhydrite. The scales were subjected to petrographic analysis and microphotographs were made which are reproduced in Fig. 7.

[13] A. de Schulten, *Comptes Rendus*, Vol. 90, 1493, 1880; *Bull. Soc. Fran. Min.*, Vol. 3, 150, 1880.
[14] A. de Schulten, *Bull. Soc. Fran. Min.*, Vol. 5, 7, 1882.
[15] A private communication.

TABLE I.—CHEMICAL ANALYSIS OF MUD DRUM DEPOSIT WHICH WAS IDENTIFIED BY PETROGRAPHIC ANALYSIS AS A CALCITE, ANHYDRITE AND A FEW CRYSTALS OF ANALCITE

Constituent	Per cent
Iron and Aluminum Oxide ($Al_2O_3.Fe_2O_3$)	11.48
Silica (SiO_2)	2.80
Calcium sulphate ($CaSO_4$)	1.45
Calcium carbonate ($CaCO_3$)	76.95
Magnesium carbonate ($MgCO_3$)	3.72
	96.40

In these photographs the anhydride and analcite are not readily identified and only the rhombohedrons of calcite are apparent. This photograph is of special interest since it shows the sharp line of demarcation between the graphite coating, with which the boiler had previously been painted, and the calcite scale.

Pittsburgh Testing Laboratory Organizes National Weld Testing Bureau

The Pittsburgh Testing Laboratory, which maintains laboratories, branches or personnel in the principal industrial centers of the United States, announces the organization of a Welding Division to be known as its *National Weld Testing Bureau*. This new Division will be headed by James W. Owens, an internationally known welding engineer, as its director.

The BUREAU proposes to render a complete welding service to manufacturers, fabricators, contractors and firms or corporations, along six separate and distinct lines, namely, *Reports on Welding Processes*, *Reports on Weld Specimens*, prior to construction (what has been termed "Qualification of Welders") *Reports on Weld Specimens* during construction, *Laboratory Tests of Weld Specimens*, *Inspection of Welded Products and Structures*, and *Investigation of Special Welding Problems*.

The Homestead Valve Manufacturing Co., Coraopolis, Pa., have just appointed the F. J. Evans Engineering Company, 1305 Watts Building, Birmingham, Alabama, as exclusive representative covering the State of Alabama for the sale of the "*Hypressure Jenny*," a vapor spray machine used for automotive, industrial, aeronautical and building cleaning.

General Electric Company and four of its associated companies have announced the removal of their offices in New York City to the new General Electric Building, 570 Lexington Avenue at 51st Street. Included are the executive offices, New York district office, air conditioning department, electric refrigeration department, Atlantic division of the incandescent lamp department, merchandise department, and plastics department of the General Electric Company, and the General Electric Contracts Corporation, G. E. Employees Securities Corporation, General Electric Realty Corporation and International General Electric Company, Inc.

New York City headquarters were formerly at 120 Broadway, where for 15 years three complete floors were occupied. Approximately 50 per cent of the new building is occupied by the company.

At the service building of the company, at 414 West 13th Street, are located the field engineering division (except the New York district engineer and the application engineering division which are in the new General Electric Building), the construction division, order service division, New York service shop, and New York warehouse.

A Review of Recent European Boiler Designs*

Several of the novel boiler designs developed recently in Europe are described generally and their advantages and disadvantages discussed. The opinions and conclusions offered are, of course, those of the author and, although they are based on sound technical and practical experience, they should be considered as such. Obviously, there is room for much difference of opinion concerning the merits of designs which differ as greatly from conventional practice as do those reviewed in this article. . . . The several designs referred to were briefly discussed in an editorial "Trends in Boiler Design" in the March issue of COMBUSTION at which time we promised to publish an article along the lines of the one here presented.

IN THE past year or two, a number of entirely novel steam generator constructions have been described in various publications. Of particular interest among these designs are the steam generator of Brown-Boveri, the rotating boiler of Vorkauf, the Zoelly boiler having conically shaped tubes and the Sulzer boiler which is built out of a single, long, coiled tube.

It is of interest to survey the merits of these new constructions and to inquire into some of their advantages and disadvantages when considering them as practical advancement over the present art in boiler constructions.

The Brown-Boveri Steam Generator

The construction of this novel steam generator has been described in periodicals[1] so a detailed description will be avoided. In general, fuel is injected into the combustion chamber of the generator under pressure and combustion is maintained under pressure. There are two methods employed, combustion under constant pressure and combustion under constant volume.

In the first of these two types, shown schematically in Fig. 1, the combustion chamber is fed with a mixture of compressed air and gas or oil. According to reports, trials have been made using brown coal (similar to lignite) dust as a fuel and also with pulverized coal. The mixture is ignited in the combustion chamber and initial ignition is produced with a torch. Maintenance of ignition is accomplished by lining the combustion chamber with refractories and utilizing their accumulated heat.

The combustion of the fuel causes an increase in volume of the gases within the combustion chamber and would result in a considerable rise in pressure were it not that a relatively large volume of the gas can escape through the heating surface of the boiler *b*. By means of the resistance of the boiler and the remaining apparatus through which the gases must flow, the pressure within the combustion chamber is maintained at about 28 lb. absolute. The pressure drop through the heating surface is about 7.1 lb., the drop through the turbine about 14.2 lb. and the drop through the economizer about 7.1 lb.

Because of the high pressure drop available, the gases flow through the boiler tubes at very high velocities, from 650 to 980 ft. per sec. In order to utilize this velocity with a minimum of loss, the boiler tubes have rounded entrances and the exits have expanded openings so as to convert the leaving velocities into pressure to the greatest extent possible. After passing the superheater, the gases are expanded further through a gas turbine, *f*, and after passing through the economizer are led to the atmosphere through a short exhaust pipe. The gas turbine furnishes the drive for the air and fuel compressors. Depending on the pressure maintained in the combustion chamber, the power consumption of the gas turbine for producing the rating amounts to from 15 to 30 per cent of the boiler load.

Because the natural water circulation in the boiler would be insufficient to properly cool the tubes, due to the small overall size of the unit, and because the high gas velocity through the tubes results in a very high rate of heat transfer, it is necessary to have a water circulating pump *k*, so that the quantity of circulating water will exceed several times the steam quantity.

The steam and water mixture is led from the boiler to a separator wherein the steam is mechanically separated from the water. The steam passes to the superheater and the water to the circulating pump. The circulating water unites with the preheated boiler feedwater and again passes into the boiler.

A claimed advantage is very high combustion rates and therefore a relatively small space occupied. In an experimental unit, in a furnace of 37.1 cu. ft., a combustion rate of 880,000 B.t.u. per cu. ft. per hr. was attained without any combustible matter in the flue gas. As a consequence of the very small space requirements, a special boiler room becomes unnecessary in most cases.

Another advantage is the very high transfer rates attained. The experimental boiler delivered 24,800 lb. of steam at 400 lb. pressure and a temperature of 716 fahr. with 187 fahr. feedwater temperature. The total heating surface in the boiler was 245 sq. ft., in the superheater 285 sq. ft. and in the economizer 710 sq. ft. The transfer rate for the combined total surface, that is, for the so-called equivalent surface, was accordingly 20.5 lb. of steam per sq. ft. per hr. The exit temperature was 320 fahr. The efficiency was given at 90 per cent, wherein, however, the equivalent amount of steam or heat used for auxiliary purposes apparently has not been considered.

The construction may be compared with that of a gas turbine. The combustion chamber is loaded with an explosive mixture and ignited. The released energy in the gases, after expanding through the boiler and yielding up considerable heat there, acts upon the turbine blades and just that much heat is withdrawn from the gases as is necessary to perform the work of compression. The gases then leave the turbine with a certain over-pressure and thereafter pass over further heating surface such as the economizer.

The question arises as to whether or not the work involved in compression lowers the overall efficiency. The inventor

* Contributed by a German Correspondent.
[1] V.D.I. No. 42, October 15, 1932.

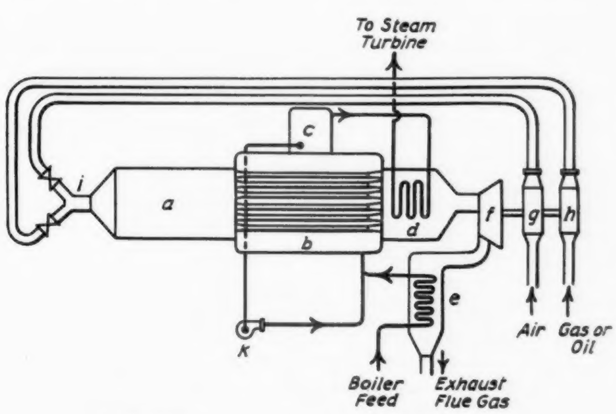
claims that it does not do so because a gas turbine has been used, but should a portion of the steam generated within the unit be used, or an electric motor be used for driving the compressor, the situation would be different. Because the work for compression may amount to about 30 per cent of boiler output, the answer to this question is highly important.

It is not clear how by directly extracting heat from the gases for the work of compression, a lowering in overall efficiency of the unit may be avoided, while a conversion of such heat into steam and then using the steam in a turbine wherein the heat of the exhaust is reclaimed, should lower the overall efficiency. There is about a 14.2-lb. drop in the expansion of the gas through the turbine. The equivalent heat drop for this purpose is therefore not available for heat transmission to the boiler water, but is utilized in producing velocities. The velocities are in part converted into useful work and are in part dissipated by turbulence within the heating surface and partly lost in exit energy in leaving the flue. Thus an efficiency of compression must be considered when directly using the products of combustion for the work of compression. However, since the heat of compression is returned to the boiler, there is some reduction in the cost of operating auxiliaries. In the usual boiler, the products of combustion are drawn over the heating surfaces by an induced draft fan, while in the Brown-Boveri boiler they are forced through. Essentially there is no difference between the two methods and in both cases the energy for transporting the gases over the heating surfaces must be deducted from the overall efficiency. In addition to the work of compression, there must also be considered the energy used by the circulating pump. Under these circumstances an overall efficiency of 90 per cent, as claimed, seems high.

It is not clear, off hand, why the unit should be cheaper than the usual boiler units of equivalent capacities when considering that it involves a gas turbine, compressors and a circulating pump, all costly equipment. Another question that arises is whether the multiplication of auxiliary machinery tends to impair the dependableness of service.

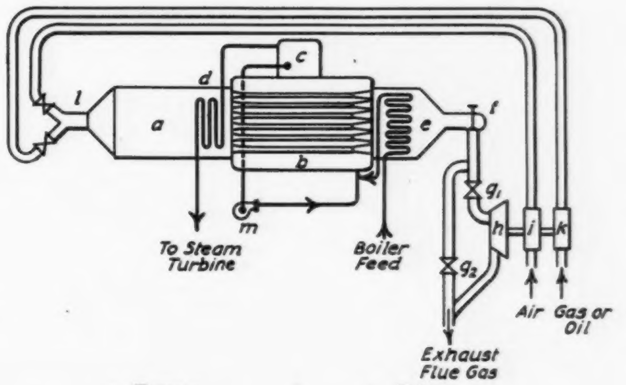
Conceivably the construction may be utilized for other fuels than washed gases or oils, such as coals. No doubt the gas turbine would suffer a short life from the bombardment of ash dust particles from coal fires. Likewise, undesirable abrasion of the heating surface would probably occur where velocities over the heating surfaces are from 650 to 980 ft. per sec.

In the second type of steam generator, employing combustion under constant volume, Fig. 2, the combustion chamber is charged with a mixture of fuel and air at about 28.4 lb. absolute. The relief or exhaust valve f is closed during this period. The mixture is ignited and the pressure rises to four



a	Furnace	f	Gas turbine
b	Boiler	g	Air compressor
c	Separator	h	Gas compressor
d	Superheater	i	Mixing valve
e	Economizer	k	Circulating pump

Fig. 1—Schematic drawing of Brown-Boveri steam generator, constant pressure type



a	Furnace	g_1–g_2	Valves
b	Boiler	h	Turbine
c	Separator	i	Air compressor
d	Superheater	k	Gas compressor
e	Economizer	l	Mixing valve
f	Release valve	m	Circulating pump

Fig. 2—Schematic drawing of Brown-Boveri steam generator, constant volume type

or five times the charging pressure. Relief valve f then opens and the gases flow at high velocity through the heating surfaces. When valve g_1 is open and valve g_2 closed, the gases flow through the turbine h, which does the work of compression. When expansion has about reached the charging pressure, the inlet valve opens. The remaining products of combustion are either pushed through the gas turbine or out through a special exhaust valve g_2 into the atmosphere. The cycle is then repeated. In order to approximate uniform flow of air through the compressor and a uniform flow of gas through the gas turbine, several combustion chambers are provided for the boiler which operate in successive rotation.

The advantages claimed by the inventor are the same as those for the constant pressure units. The disadvantages appear the same also, with the addition of five valves which must be continually controlled. There is an impulse-like generation of steam which may be of doubtful value to the boiler. The impulse-like flow through the gas turbine under variable pressure surely reduces the blade efficiency of the gas turbine.

The Vorkauf Rotating Boiler with Turbine Drive

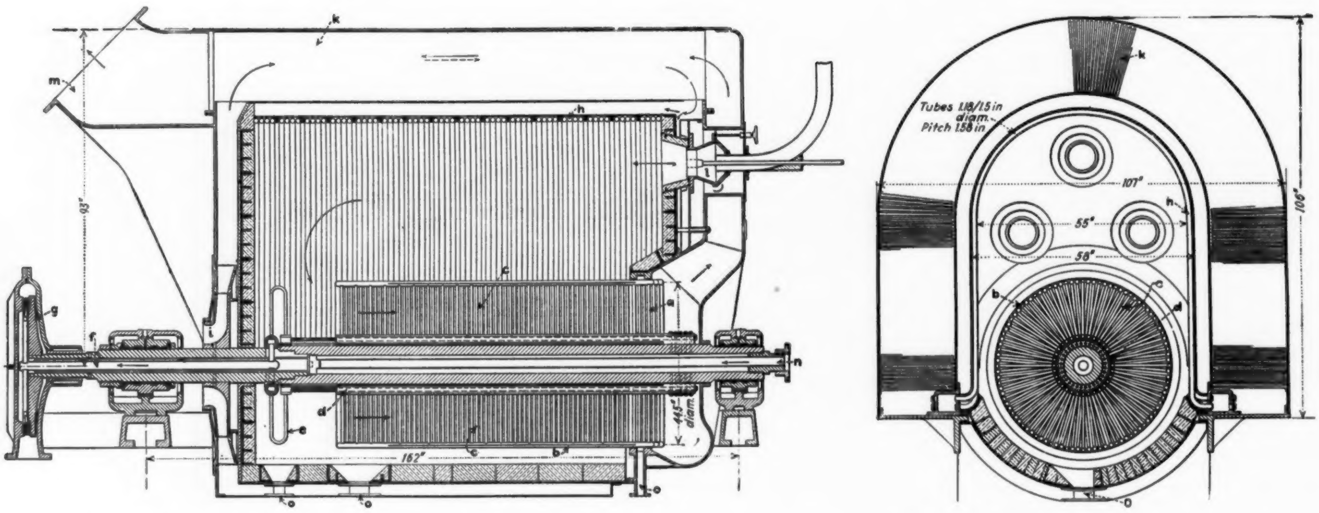
Vorkauf's boiler[2] adapts the principle of the rotating pump and employs it in a rotating U-shaped loop having its closed end at the periphery of rotation and its open end at the shaft. Water is fed into one leg of the loop at the shaft and the loop is so heated that steam accumulates in the other leg and the outflow of this steam resisted, as by a throttle or turbine. Depending on the speed of rotation, the unbalanced centrifugal forces between the leg filled with solid water and that filled with steam will build up a steam pressure on the steam side, which will maintain the balance between the two legs and hold back the water out of the steam leg. The loop then serves as a boiler feed pump and the usual feed pump is dispensed with. The boiler being built up of a number of such loops connected in parallel then becomes its own feed pump.

Referring to Fig. 3, c designates the boiler tubes. Boiler feedwater flows through the hollow shaft into the radially arranged boiler tubes. Steam flows inwardly toward the shaft, thence into the superheater e and to the driving turbine g. Exhaust steam from the driving turbine flows to the reheater h and thence to the main turbine.

Air for combustion is preheated in the semi-circularly formed air heater and enters the combustion chamber in part through the three oil burners and in part through the reheater h. The products of combustion flow over the superheater e, thence over the boiler c and finally through the air heater k. Draft is furnished by the rotation of the boiler.

The advantages which the inventor claims for his design of boiler are: Heat generation within a very small space; high

[2] V.D.I. No. 41, Vol. 8, October, 1932.



a Water supply tubes	*g* Turbine	*m* Waste-gas flues
b and *c* Evaporator tubes	*h* Reheater	*n* Water supply pipe through the hollow shaft of the coupled generator
d Steam collectors	*i* Fresh air compressor	*o* Ash and dust discharge connections
e High-pressure superheater	*k* Air heater	
f Steam collector tube	*l* Burners	

Fig. 3—Vorkauf rotating boiler

rates of heat transfer, hence a small amount of heating surface; no boiler feed pump necessary since the in-flowing boiler feedwater varies automatically in proportion to the heat input because the mixture in the steam contained in part of the tubes becomes heavier or lighter due respectively to a reduced or increased steam content; no danger of explosion because drums are avoided; no special device is required for the forced draft fan; self-cleaning ash removal, in that the ashes are hurled into the ash discharge connections *o* by the rotating boiler heating surface; an approximate 60 per cent saving in cost of installation for a unit of 40,000 lb. steaming capacity in comparison with a unit of the usual type, even when neglecting the possible saving due to building costs.

In an experimental model, the resulting pressures were measured for various revolutions of an element in which one leg of the rotating U-bend boiler element was isolated so that only water could be present within it, while the other leg was heated to such intensity that practically only steam was present within it. The pressures measured were in entire agreement with theoretical calculations for the differences between the centrifugal and centripetal forces. In actual practice it would be impossible to convert a surge of water from the centrifugal leg completely into steam within the centripetal leg. The difference in densities would therefore be smaller in practice. Consequently, materially greater revolutions of the element would be required than determined by the model and the theoretical calculations, perhaps up to 5000 r.p.m., or a larger diameter of element would be required to attain an acceptable pressure.

In the design, the cross-sectional areas for the leaving steam seem very small. The practical development of caring for the steam flow through the superheater and to the driving turbine would appear to offer difficulties.

Because of large masses turning at high speeds, great precaution must be taken in the accuracy of workmanship. The rotor must be as carefully built as that of a steam turbine.

Due to an unequal heating of the elements, for example by clogging of part of the heating surface and consequent unbalanced steam generation, the rotor may become unbalanced and cause considerable vibration which may cause injury to the rotor.

One may imagine that the salts and hardness-forming constituents unavoidably contained in the feedwater may pass into the vapor in the form of dust and be carried over to the engines driven by the steam and that they may deposit within the tubes and destroy them, for there is no excess water circulating to retain such dust in solution.

Essentially only gases or oils may be used as fuel for this type of boiler. It is questionable whether pulverized fuel may be burned in the combustion chamber as shown. The inventor maintains, however, that turbulence produced by the rotation of the boiler within the combustion chamber comes into play and greatly increases the rate of combustion. Turbulence may of course cause higher combustion rates, but it seems doubtful whether combustion rates of 340 to 550 thousand B.t.u. per cu. ft. of combustion space can be obtained.

The inventor maintains that pressure rise of the water requires no outside work. This is doubtful, because the pressure rise is obtained only by the rotation of the boiler. The driving turbine *g* is, so to say, the drive for the boiler feed pump which, in this case, is the boiler itself. In order to have a reasonable working pressure on the driving turbine, a pressure considerably higher than the service pressure must be carried on the rotating boiler which in turn will involve a relatively higher number of revolutions.

It is an interesting question whether fluctuations in load can be met by the boiler which serves simultaneously as feed pump, forced draft fan for secondary air and induced draft fan. It is not disclosed whether, for example, the revolutions must vary with load fluctuations. One might assume that with a drop in load, the revolutions should increase in order to maintain the pressure, because less steam would be present in the steam-water mixture of the steaming leg of the U tube. Such an increase in revolutions at reduced load would, however, be unsuitable for the draft and pressure conditions of the furnace and would involve undesirable throttling by dampers.

Undoubtedly the boiler costs of such a boiler cannot be low because the boiler becomes structurally a precision machine.

The Zoelly High Capacity Steam Generator

The Zoelly steam generator,[3] when compared to the previously reviewed types of boilers, is constructed more nearly like the conventional designs. There is at least a combustion chamber of usual size.

The characteristic of the Zoelly boiler is the conical, upwardly-enlarging tubes which are built, for constructional reasons, of a series of superimposed cylindrical tubes, increasing in diameter upwardly. In the disclosure in the article referred to, the tube is built up in four lengths.

Zoelly's basis of design involves the theory that as pressures rise the steam releasing surface may be smaller for equal quantity of steam released, and that eventually the tubes themselves may be used for the steam release from the surface of

[3] *Wärme*, No. 43, October 22, 1932.

the water. Because the cross-sectional area of the usual tubes would not be sufficient, he enlarges the tubes toward the top and arrives at a desired area where carry-over of the water by the steam no longer happens. The tubes are fed from the bottom. Within the tube some sort of turbulent circulation will occur and near the top end a constant water level is maintained. The steam is collected from each individual tube and piped to a superheater.

The advantages claimed are: Low cost of unit because it dispenses with the use of drums, a high safety factor in operation and simplicity of construction.

The drum saving is obvious, but other details of construction involved seem relatively costly. Undoubtedly the heating surface required for a given output must approach closely that required in the usual boiler. All tubes must be built up in conical shape and must be carefully welded, which adds to the cost of the heating surface. It would not seem satisfactory to have welded seams of such large diameter tubes as are required exposed to furnace heat. A large number of headers must be supplied, for each tube requires a steam riser tube, all of which riser tubes in turn lead to collectors from which the superheater is fed. The distribution of feedwater to the bottom of tubes, subject to variable heat impingement of the furnace, seems a problem.

It is claimed that experiments have shown, that with large load fluctuations the water level in the tubes varied but little. This finding is submitted as proof of its safety of operation at high ratings. The sketch shows the gage glass connections to be to the steam collector and to the lower water headers and it is well known that internal fluctuations are not recorded by a gage so connected. A gage so connected measures only the weight of the steam-water mixture within the tube system, which weight remains fairly constant during minor fluctuations. The water level thus indicated is only an apparent level and the true level may only be determined by having the water connection to the gage up near the water level on the tube. Further, depending on relative weights of steam-water mixture within the tube and of the solid water in the bottom gage glass connection, the level recorded by the experimental gage must have been far below the actual level within the tube. As long as moisture measurements are not available, it may be contended that considerable water may be carried into the superheater.

In an article* published in *Warmewirtschaft*, November, 1932, page 292, it was shown that steam release is mainly dependent on steam space volume and not upon steam releasing surface. Should then high water levels exist within the tubes

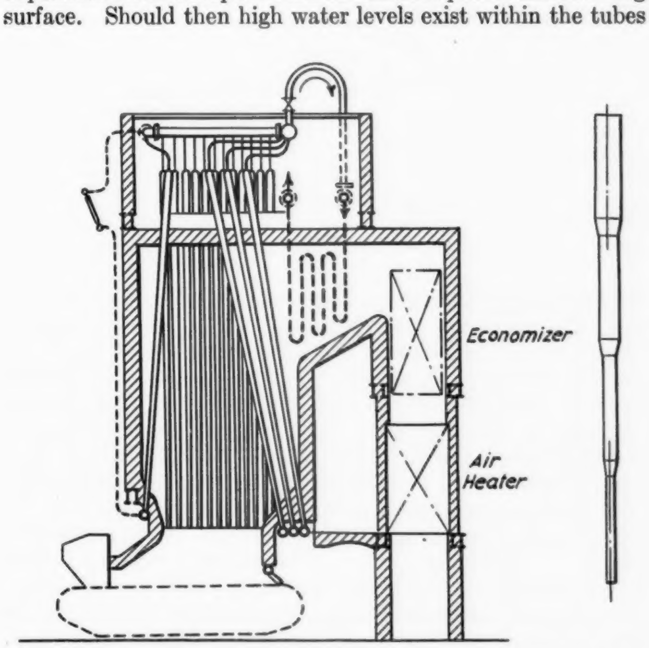
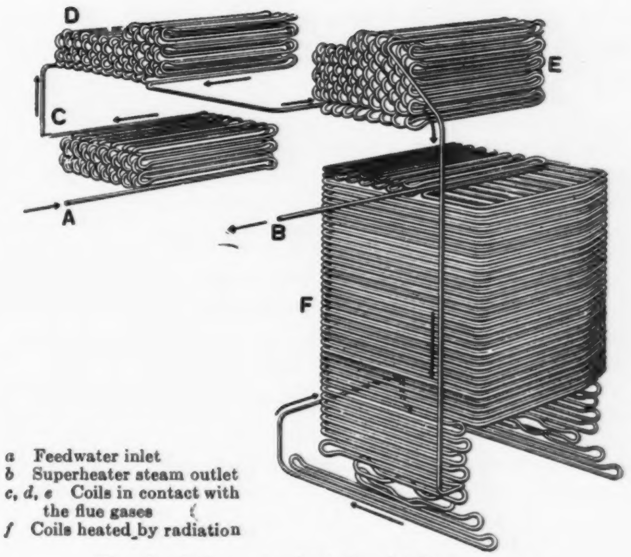


Fig. 4—Zoelly steam generator. Single tube shown at right



a Feedwater inlet
b Superheater steam outlet
c, d, e Coils in contact with the flue gases
f Coils heated by radiation

Fig. 5—Sulzer single-tube, high-pressure steam generator

and should surges occur, it is quite likely that considerable water will be carried over into the superheater.

Regarding its simplicity: The feedwater problem is more complicated than feeding into a drum. The steam collection is more complicated than by means of a drum or drums. The tube construction is more complicated because, as far as one can learn from publications, one must assume that the steam risers must be removed to clean the tubes. Because of the conical tubes, the free area for the flue gases between tubes decreases upwardly and to have a uniform contacting of the tubes by the gases, complicated refractory structures are required.

The Sulzer-Single Tube High Pressure Steam Generator[4]

According to the description, this boiler is made out of a single continuous tube. Feedwater is pumped through and after passing through the economizer, boiler and superheater zones, the steam leaves the other end. Drums, headers and down-comers become unnecessary.

For a steaming capacity of 22,050 lb. per hr. the tube is said to have a length of 2.5 km. A rough calculation gives a tube of about 2 in. (50 mm.) outside diameter.

In this boiler, like the Benson boiler, it is most important that heat liberation and water circulation are continuously and exactly coordinated. A pulsating feed, as with standard boilers with drums, is out of the question. Therefore, a complete automatic regulation is necessary which holds the steam pressure and the temperature of the superheated steam continuously constant and the boiler feed in relation to the heat liberation.

The inventors claim: Safety of operation because of forced circulation; cheapness because of omission of drums and headers; simple attendance because of automatic regulation of feed, pressure and temperature.

If correct, that there is only a single tube of 2.5-km. length for a generator having a steaming capacity of 22,050 lb. per hr., the exit velocity from the tube of 50/40 mm.-dia. would be 2430 ft. per sec. The pressure required to maintain such a velocity would alone be enormous and the power input would be prohibitive. However, several parallel circuits may be chosen, but from the reports of Benson boilers it is known that splitting the flow through several tubes presents difficulties. Distributing headers then become necessary at both ends of the tubes and a collector for the steam.

* A translation of this article was published in the April 1933 issue of Combustion.

[4] *Wärme*, No. 46, Vol. 12, November 1932.

For feedwater, condensate is recommended. Pure condensate, however, is an iron solvent, and it becomes necessary to carry a slight alkalinity. Because blow-down is not possible, all chemicals added must either deposit as scale in the tube or be carried on by the steam to the turbine.

Feedwater must be varied with heat liberation. With sudden fluctuations, such regulation alone would be insufficient because of the long tube length. Therefore, a sensitive superheat-temperature regulation must be added which injects water. Because the superheat rises at high ratings, further regulation is required. The automatic regulation seems complicated and does not necessarily determine the safety of operation.

It may be of interest to review the subject-matter of a British patent recently issued to Krupp, in which various control means are provided in a once-through-flow type of boiler to meet the difficulties encountered in operation. To stop the salts and hardness forming constituents passing into the vapor in the form of a dust, which may deposit on the tubes or be conveyed to the engines by the steam, an excess amount of water, above that to be evaporated, is pumped through the boiler. On an average the excess is about 10 per cent. The excess water retains the undesirable dust in solution and is separated from the steam in a specially designed separator. It is finally wasted in a concentrated state through heat exchangers. The amount of excess must be such that the limit of solubility of the substances dissolved in the feedwater is not exceeded during vaporization so that these substances are retained in the water. Where the feedwater is high in bicarbonates or similar substances which separate prior to vaporization, the solubility is increased by addition of acid. Because of the impossibility of maintaining a definite alkalinity with such treatment, an apparatus is provided for the separation of the gases from the feedwater so as to weaken the oxygen attack on the tubes. This excess water, taken off ahead of the superheater, also overcomes the difficulty of varying steam temperatures due to more or less water surging into the superheater and overcomes the coincident shock-like vaporization.

To accomplish all of the above, auxiliary control means are required to accurately insure the desired ratio of excess water to total feedwater, supplemented by manual control for different loads. The feedwater flow is controlled by automatic means involving a combination of rate of steam flow and rate of excess water flow within the steam separator and is supplemented by manual control. Other control means are necessary to synchronize the fuel supply with the feedwater flow and steam temperature.

The Krupp steam generator of once-through-flow type disclosed, as well as some recent Sulzer patents, use several tubes in parallel for the water and steam flow. Under variable load conditions, either the amount of excess water is varied, as in Krupp's design, or the tubes are connected in parallel, series-parallel or series to maintain a desirable velocity of flow therethrough.

The foregoing new types of boilers are of interest and, though apparently simple in principle, tend to lead to the conclusion that the desirable and more complete construction is the one that is the simplest in its means for accomplishing its purpose.

Alabama By-Products Corporation announces that A B C Coal & Coke Company has been organized as successors to Hammond Iron Company in selling and distributing their coal and coke, effective August 1st.

The new selling organization will have the same officers, same personnel and same location as Hammond Iron Company.

All orders and sales contracts heretofore made through Hammond Iron Company will be executed and carried out by A B C Coal & Coke Company.

Chart for Calculation of Fuel Values and Costs

The Fuel Engineering Company of New York have recently published the *Fuel Valuegraph*, a chart prepared for the rapid calculation of fuel values and costs.

Fuel costs depend upon three distinct factors and their relation to each other—the heat value of the fuel, the efficiency of the plant and the price of fuel. This chart can be used to determine graphically the effect of any combination of these three factors.

The Fuel Valuegraph is put up in pads that sell for $1.00. These pads can be obtained from the Fuel Engineering Company of New York, 116 East 18th Street, New York.

The Superheater Company, New York, has appointed William T. Conlon manager of its Industrial Department. In this capacity, Mr. Conlon will have charge of the design, manufacture and sale of Elesco superheaters for all types and makes of boilers for public utility and industrial power plants. The products of this department also include desuperheaters, resuperheaters, furnace water walls and miscellaneous heat exchange apparatus for power plants and process industries.

Since November 1929, Mr. Conlon has been serving in an executive sales capacity. Prior to joining The Superheater Company, he was associated with the Utica Gas and Electric Company. Mr. Conlon is a graduate mechanical engineer from Purdue University, class of 1920.

The Coppus Engineering Corporation, Worcester, Mass., has appointed John O. Weber, 122 Main Street, Louisville, Ky., representative for the state of Kentucky, excluding Boone, Kenton, Campbell, Pendleton, Bracken, Mason and Lewis Counties, which will continue to be served from the Cincinnati office.

Mr. Weber, who is widely known in the Blue Grass state, will have charge of sales in this district of the entire Coppus line of forced draft and ventilating blowers, man-cooling fans, steam turbines and turbo-generators.

Consolidated Gas Company announces that a life-size bronze bust of the late Thomas A. Edison has been placed in a special memorial niche in the main hall of its building at 4 Irving Place.

This bust, which has been approved as "official" by the Edison family, is dedicated to the memory of the inventor of the electric light bulb, and the founder of the first electric company in New York City.

The American Standards Association announces the election of E. J. Rutan, superintendent of the Testing Department, New York Edison Company, to the chairmanship of the recently organized Sectional Committee on Electrical Measuring Instruments. H. C. Koenig, of the Electrical Testing Laboratories, New York, was elected secretary.

The work of the committee will be handled by two subcommittees, one on Definitions, and the other on Classification, Rating, Methods of Testing and Construction.

At its recent organization meeting, the sectional committee, in its capacity as adviser on indicating electrical instruments to the U. S. National Committee of the International Electrotechnical Commission, formulated proposals for consideration by the international advisory committee which met in the latter part of June.

Patents*

By GEORGE RAMSEY, New York
Patent Lawyer-Member A.S.M.E.

PART XI

Interference Procedure (Continued)

Mr. Ramsey continues his discussion of preliminary statements indicating the conditions under which amendments to such statements can and should be made. As pointed out previously in this series, the assignment of a patent does not have to be recorded until after the application has been allowed. The author shows the significance of this fact in connection with interference proceedings. He outlines the relationship of the different parties in interference proceedings and discusses the various steps, motions, etc., available to these parties. The concluding part of the article points out the possibilities of dividing applications so as to limit the claims involved in interference or to permit the uninterrupted prosecution of claims not involved and tells how interference proceedings are terminated.

Amending Preliminary Statements

WHEN the inventor is confronted with the necessity of determining the dates required for his preliminary statement, it is usually difficult to arrive quickly at the correct dates. This is especially true where the application has been pending for sometime and the dates are somewhere in the distant past. The inventor naturally turns over the subject-matter in his mind and attempts to reconstruct the incidents which lead up to his making the invention. These events usually concern a conversation with some fellow artisan. Sometimes the person with whom this conversation occurred has moved away and it requires time and effort to locate him. In the meantime, the inventor may decide that he has the correct dates, and the preliminary statement may be made up on this basis. Then, to his surprise and consternation, some incident may arise and call to mind an earlier date or in the meantime he may have found the persons with whom he originally discussed the invention and they may point out some fact which establishes an earlier date. The inventor naturally is desirous of setting forth the correct dates in his preliminary statement and the question is just what he can do to correct the error.

If the error is discovered before the time for filing preliminary statements has expired, the inventor may file an amended statement without any difficulty. If the time for filing preliminary statements has expired and the Examiner of Interferences has opened the sealed envelopes containing the preliminary statements, the inventor will have great difficulty in amending his preliminary statement to carry his dates back to earlier dates than those which he originally specified.

When the preliminary statements are opened and it is found that each pa-ty has set up a date of conception of the invention which antedates the filing date of the application of his opponent, then all parties are entitled to see their opponents' preliminary statements and are entitled to inspect and make copies of their opponents' applications. Interfering applications are exceptions to the rule of secrecy of the Patent Office, so far, only, as the several parties to the interference are concerned. All parties thereby are fully apprised of the dates which their opponents will attempt to prove. Consequently, if amendments to preliminary statements were freely allowed after the parties had seen their opponents' statements, the very fundamental intent of the practice of requiring preliminary statements would be destroyed. The sole purpose of a preliminary statement as we have pointed out is to make a skeleton record of each party's case before he has any knowledge of his opponents' case.

Where the preliminary statement of one party does not go back of the date of filing his opponents' application, then his opponents' preliminary statement is sealed and the last party to file his application is not permitted to inspect it. Nevertheless, he is permitted to inspect the other party's application and to make copies of his opponents' application and drawings. Even under these conditions, where he has not seen his opponents' statement and, therefore, does not know his dates, the Patent Office will not permit a party to amend his preliminary statement as a matter of course, because he has had the advantage of seeing his opponents' application.

It is possible at any time to amend a preliminary statement to set up corrected dates providing it can be established to the satisfaction of the Patent Office Officials that the information as to the true facts was so concealed or so inaccessible that it could not have been obtained within the time set in which the preliminary statements were originally prepared. The party who seeks at a late date to amend his preliminary statement has a difficult job and must produce convincing evidence that the information could not have been obtained sooner.

The procedure to amend a preliminary statement, after time for filing has passed, is to obtain affidavits setting forth the true facts and the incidents leading to the discovery of the true facts and the reasons why the true facts could not have been discovered earlier. These affidavits should be attached to and made a part of a motion to amend the preliminary statement which is filed before the Examiner of Interferences.

It occasionally happens that, during the taking of testimony, facts of a surprising nature will develop which show that the preliminary statement is wrong. When this occurs, a motion to amend the preliminary statement based upon the testimony should promptly be filed with a request that the proceedings be stayed or stopped until the motion is disposed of. The Examiner of Interferences will usually act promptly upon such a motion and in most cases will deny the motion but will authorize the taking of testimony to support the new dates and will permit the parties to argue at final hearing as to whether or not the testimony justifies the amending of the preliminary statement.

All such motions are what are known as "interparties motions," that is, such a motion must be served, together with the supporting affidavits, upon opposing counsel. If the motion is in proper orm, it will be set for hearing before the Examiner of Interferences and opposing counsel has a right to appear and argue against the granting of the motion. Such motions to amend preliminary statements are granted only under very exceptional circumstances. There is no appeal

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from the granting or denial of such a motion. However, later on in the progress of the case, the same question may be argued at final hearing, which will be explained later, and may be carried up on an appeal from the final decision.

While preliminary statements are papers of estoppel, nevertheless, opponents are vitally interested in each other's prepreliminary statements and it may be that an opponent's preliminary statement is not sufficiently definite to fully hold him to specific dates. Under these conditions, the other party may bring a motion, which is in effect a petition, that his opponent be required to clarify his preliminary statement by further declarations. This is an unusual procedure but it has been done. Such a motion is heard by the Examiner of Interferences and, since it is not provided for by the rules, there is no appeal from the Examiner of Interference's decision. However, the aggrieved party may take a petition to the Commissioner, who, of course, at all times has full jurisdiction over the entire Patent Office. The Commissioner may dismiss the petition, which amounts to affirmance of the action of the Examiner of Interferences, or he may write an opinion reversing an action of the Examiner and granting the motion.

Formal Amendments to Preliminary Statements

The preliminary statements are opened and examined by the Examiner of Interferences, or one of his assistants, and if they are found to be faulty or defective in some particular relating to form, the party making the error will be notified of the formal defect and be given a time to file an amended statement correcting it. There is no trouble with this kind of an amendment. It was suggested by the Patent Office in the first place and it goes only as to form in the second place. Amendments desired by the contestants go to the substance of the matter and here is where the trouble comes in. In the meantime, neither party will be allowed to see the statement of his opponent until after the party in error has had an opportunity to correct his statement within the time given by the Patent Office. Such a defective preliminary statement will be removed from interference file and preserved by the Patent Office, but will not be open to inspection by the opponents in interference without authority from the Commissioner.

The preliminary statement in an interference while it is under oath is not in any sense evidence in the case. It is merely an estoppel paper which prevents unscrupulous parties from trying to change their minds or set up fictitious dates after they know the dates of their opponent.

Recorded Assignments—Interfering Applications

We have noted that the assignment of an application need not be recorded in the Patent Office until the application has been allowed. We have also noted that the assignment records are open for public inspection and that recorded assignments give the name of the inventor, the title of the invention, the filing date and serial number of the application.

While it is advisable to have an assignment of an application executed at the time the inventor executes the application, it is often advantageous to withhold recording the assignment until the application is allowed because if the application gets into interference, it is likely the first thing the opponent will do as soon as the interference is declared is to look up the assignment records and see if he can identify these records with the inventors' name and the title of the invention given in the declaration of the interference. If he can he is immediately informed as to the date when his opponent's application was filed and he may use this information to his own advantage.

Furthermore, we have noted that where a common assignee of record in the Patent Office owns several applications directed generally to a common invention, which become involved in an interference with some third party, the common assignee is required to elect which of the several applications that he owns shall go into the interference. It is sometimes difficult to decide which application to elect, because one application may be best for the interference as to certain counts, whereas the application of another inventor owned by the same assignee may be better as to other counts. If there are no assignments of record as to these several commonly owned applications, the Patent Office will not require an election, and, therefore, more than one of the applications will go into the interference, and during the progress thereof or after the interference is over, the common assignee may then select the particular claims which should go into each particular application.

Burden of Proof

The burden of proof in an interference is on the party who files last and if there are three or more parties involved in an interference, the burden of proof is inversely in order of their filing dates. The party who has filed his application first is known as the "senior party" and the party who has filed last is known as a "junior party." Where more than two parties are involved in an interference, their position as to "junior" and "senior" is in inverse relation to the chronology of their filing dates, that is, if A, B and C have successively filed applications for patents, A will be the senior party of the interference and C will be the junior party. B will be a junior party as to A and a senior party as to C. This order of junior and senior parties in interferences determines the order in which the parties are to take testimony and their burden of proof relative to the other applicants involved in the interference.

Where a party does not file a preliminary statment he will be restricted to the filing date of his application, that is, this date will be held to constitute his date of conception of the invention, his first drawing and written description, his disclosure to others and his constructive reduction to practice.

Interfering Applications Open to Inspection by Opponents

As soon as the preliminary statements have been opened and accepted as complying to the formalities of the Patent Office, these statements may be inspected and copies thereof may be had by all parties to the interference. When the preliminary statements are opened, the files of the applications of all parties to the interference are open for inspection by each other, that is, if A and B are in interference, A may obtain a complete copy of the application file of B, and B may obtain a complete copy of A's application. In this way, all parties can see the other party's cases, and then the real scrap begins.

Any party to the interference who fails to file a preliminary statement will not be permitted to take testimony to prove his priority of invention. He must rely upon his filing date.

As soon as the preliminary statements are opened, the Examiner of Interferences does one of two things. First, if any party to the interference, other than the senior party fails to file a preliminary statement, or if a junior party's statement fails to overcome the filing date of the application of the senior party or parties, the Examiner of Interferences will notify the junior party that at the expiration of some fixed time, not less than thirty days, judgment on the record will be rendered against the junior party unless good and sufficient cause is shown why such action should not be taken.

Second, in a case where the preliminary statements of the parties to the interference carry their invention dates back to the filing date of the senior party, the Examiner of Interferences sets dates, sometime in the future, at which the parties involved in the interference shall take their testimony. This schedule of dates begins with the testimony in chief of the junior party, and then other dates are set within which time the testimony in chief of the other parties must be closed. The schedule for taking testimony provides that after the testimony in chief of the junior parties is in, then, the senior party shall take his testimony in chief, and after that is finished, dates are set for the respective junior parties to take rebuttal testimony.

Opponent May Be Prevented from Seeing Entire Application

We have noted that when the preliminary statements are approved and opened by the Examiner of Interferences, opponents are permitted access to each other's applications. It may happen that the feature covered by the claims comprising the counts of the interference is a sub-combination of the main invention and that the main invention disclosed in the application is not involved in the interference. Suppose, for example, the application discloses a complete transmission and clutch for an automobile, and that the interference relates only to the clutch. The applicant may feel that his opponent is not entitled to see his application in its entirety including the new transmission features not involved in the interference.

If his application has been properly prepared so that each part has been described as an entity, he may file a certified copy of the part only of the application which discloses the invention which is covered by the counts comprising the issue of the interference. Such a certified copy should contain the exact words of that portion of the application which relates to the interference and should show the exact figures of the drawings or portions of the figures which illustrate this invention. The Patent Office will certify to this mutilated application as being a true copy of the portion of the original application filed on such and such a date and it is the only part of the original application involved in interference. The opponents will be permitted to inspect only the certified copy and will not be permitted access to the original application and drawings. In order to obtain such a certified copy, the applicant must reach an agreement with the Primary Examiner as to what part of the original application shall go into the certified copy and as to what part of the original application may be withheld from inspection by the opponent. When the agreement is reached, the certified copy will be prepared by the Patent Office and the usual charge for preparing and certifying documents will be made by the Patent Office. When such a mutilated copy is submitted and accepted by the Officials of the Patent Office as correctly showing all of the interfering subject-matter, the interference will proceed with the mutilated copy. Since the purpose of this proceeding is to prevent an opponent from seeing features which are not involved in the interference, it is obvious that this proceeding should be instituted before the application is laid open for inspection by an opponent. Therefore, this step should be taken sometime after the interference has been declared and before the time for filing preliminary statements has expired. The original application will be held in abeyance until the interference is settled.

During an interference, all prosecution of the application ceases. That is, the applicant is no longer under obligation of amending his case within six months from the last Office action. As a matter of fact, the applicant is actually prohibited from prosecuting the case until the interference is over. There is one exception to this broad rule and that relates to a case containing divisible subject-matter.

Divisional Application May Be Filed During Interference

Where an original application becomes involved in interference, but the original application contains divisible subject-matter, which is not involved in the interference, the applicant may do one of two things. He may file a divisional application and ask that it be substituted in the interference for the original application, or he may leave the original application in the interference and file divisional applications upon subject-matter disclosed in the original application which is an independent invention that may be patented separately. The divisional applications go their merry way through the Patent Office just as though their worthy parent were not struggling for life in an interference battle.

This procedure may be taken at any time during the progress of the interference. If the division is made before the preliminary statements are opened, the opponent may not be permitted to inspect the original application. Where the opponent has been made senior party because of the filing date of his parent application, the junior party usually brings a motion demanding to see the parent case. This motion will likely be granted if there is a difference between the original application and the divisional application. Where the divisional application is filed after the interference has been proceeding for sometime, the original case is retained in the interference and the divisional case goes forward before the Primary Examiner in the usual way and the parties in the interference may not know there has been a divisional application filed until once the patent issues on the divisional case while the interference is still wending its weary way to hold up the parent application. If any claims are made in the divisional case, which include any subject-matter disclosed in the opponents' applications, the divisional case will be held up by the Primary Examiner until the interference is terminated. If there is any question of double patenting arising due to the filing of the divisional application, such divisional case should be held up until the termination of the interference.

One of the leading cases of the Supreme Court of the United States on double patenting arose because of this interference practice. An inventor filed an application for patent disclosing a cultivator having plows mounted on a beam which was under the influence of a double acting spring so constructed that when the beam was substantially horizontal, the spring normally urged the plows into the ground, but when the beam was lifted upwardly the spring reacted to assist in lifting the beam. The original application got into interference on the broad invention of using a spring for increasing the lifting force of the plow beam. A divisional application was filed and issued as a patent on the invention of using a double acting spring, which reacted with the plow beam at one time to force the plows into the ground, and, when the beam was lifted, reacted to assist in the lifting.

The broad patent (last to issue), based on the application which won the interference, got into litigation. The Supreme Court of the United States held this patent was void because of double patenting. This later patent had the broad claim to the lifting action of the spring, while the prior patent based on the divisional application had narrow claims to the double action of the spring which pushed down at one time and lifted at another time. The Court held that two valid patents could not issue on the same identical structure and that the later broad patent was invalid.

There is a temptation to take out a specific patent with narrow claims on such part of an application as may be pried loose from an interference. This is a proper procedure providing there is no question but that the subject-matter of the divisional application is patentably distinct from the subject-matter in interference. If it is not patentably distinct, then, the labor, cost and worry of fighting the interference is wasted because when the broad subject-matter of the interference is patented, such patent will be held to be void if the patent which issued earlier on the divisional case is not a distinct and separate invention. This is exactly what the Supreme Court decided.

In view of this complicated situation, filing of divisional cases where the original is in interference should be carefully analyzed with a competent attorney before this step is taken.

The safest bet on filing applications for patent is to file originally a separate application for each patentably divisible invention. This may be a little more expensive in the first place, but if you get into interference, only one single invention and only one application is tied up. A skillful attorney fighting every step of the way may hold up an opponent for several years through interference procedure. This course of action may prevent a patent from coming out that would cover a commercial enterprise. In the meantime, the party in danger gets busy to develop non-infringing machines or to get the

cream of the business while he is holding up his opponent and then when the interference is about to be over and the patent is about to come out, he can stop. His opponent has no redress for the things that happened before the patent issued. Filing independent applications, in most cases, will save a lot of grief if an interference is encountered.

Motion Period

The progress of an interference through the Patent Office may be divided into four divisions, first, the preliminary period comprising the declaration, preliminary statements, etc.; second, the motion period during which various motions may be brought; third, the testimony period during which testimony of the parties is taken; and fourth, the argumentative period comprising final hearing and appeals.

In the paper comprising the schedule of dates of taking testimony, the Examiner of Interferences specifies that within thirty days from the date of this communication, the parties may file various motions. This thirty day period comprises the "motion period." It is important that the motions be filed within this period. The motions will be argued long after this period expires, but if a motion is not brought within this period, the Examiner of Interferences may decline to set it for hearing. During this period, the parties may obtain copies of each other's applications and they may make searches through prior art patents, publications, etc., to determine if the count of the interference is really patentable and to discover if the Examiner has found the best prior art bearing on the count comprising the issue of the interference. This thirty day period usually is sufficient time in which to take care of the necessary work to formulate a basis for and to prepare and file the various motions.

While the Patent Office is desirous of having interference proceedings move along at a reasonable rate in order to get the patents granted as soon as possible, the Patent Office usually will grant additional time in which to take various necessary steps providing counsel for the several parties will all agree to the delay. If a counsel for one of the parties declines to agree to the additional time, then the only thing the other party can do is to bring a motion to extend the time for some particular purpose, for example, the time in which to file motions. Where additional time is required to file a motion and an opponent will not agree to giving the time, the best procedure is to notify the Patent Office of the intention to file the motion and state that the thirty day period is not sufficient for the required preparation. Then, when the motion is filed it should be accompanied by an affidavit to the effect that the motion was prepared and filed as soon as possible but that it could not have been filed within the thirty day period allowed.

Motion to Shift Burden of Proof

One of the motions which may be filed during the motion period is a motion to shift the burden of proof. It sometimes happens that a junior party has filed a continuing or a divisional application which gets into interference. After the preliminary statements are open and the junior party has seen his opponent's case, he may find that his parent application was filed earlier than the senior party's application. If the parent application clearly discloses the subject-matter of the invention in issue in interference, then, the junior party should bring a motion to shift the burden of proof. This motion should set forth the facts as to the situation and should refer specifically to the portions of the parent application which are alleged to disclose the said invention in issue. The Examiner of Interferences will set this motion for hearing. If the decision of the Examiner of Interferences sustains the motion and the junior succeeds, then his parent case goes into the interference and he now becomes senior party. By becoming senior party, the burden of proof shifts to his opponent and his opponent must take testimony to prove his case back of the records in the Patent Office. As soon as a motion to shift the burden of proof is filed, the opponents are entitled to inspect the parent application of the party bringing the motion in order that they may be in position to oppose the motion, as for example, to argue that the early case does not clearly disclose the issue of the interference. Sometimes this question of shifting the burden of proof is a very important one and a great deal depends upon the disclosure of the parent case. There is no immediate appeal from the decision of the Examiner of Interferences on a motion to shift the burden of proof but this question is of such importance that it may be argued again at final hearing and thereafter an appeal may be taken in the regular way.

Termination of Interference without Contest

After an interference has been finally declared, it will not ordinarily be terminated without judgment of priority to some party of the interference, which judgment must be founded either upon the record, or upon testimony, or upon a written concession of priority, or upon a written declaration of abandonment of the invention. The written concession, disclaimer, or abandonment, must be signed by the inventor himself and must be acquiesced in by the assignee if there is an assignee of record in the Patent Office.

After the preliminary statements have been opened and the parties are acquainted with their respective status, some party to the interference may decide for one reason or another that he does not wish to contest the interference. Of course, if he does nothing, and it is but a two party interference, the interference will terminate ordinarily at a relatively early date. If it is a three or more party interference and some party thereto decides to fight, the interference may go on for some time and the inactive party may find his application tied up so that he is unable to secure a patent until the interference is over. If it is a two party interference and neither party takes any steps, the Patent Office will decide in favor of the one who filed first. Therefore, in a two party interference, if the junior party makes no contest, the senior party has nothing to do since the burden of procedure and of proof rests on the junior party. Where one party to an interference decides to contest the interference, other parties will have difficulty in getting out of the interferences without making sacrifices, unless they are able to reach a compromise with their opponents.

In an interference of two or three parties, the parties may be able to come to an agreement. This agreement is usually based upon reaching a conclusion among themselves as to which applicant should be entitled to the patent. Then, the losing party concedes priority to the winning party in consideration of a license under his invention and any patent which may issue thereon to the winning party. The form of the license is a matter of agreement between the parties, as is the whole procedure. It may be an exclusive license or it may be a non-exclusive license dependent upon the arrangement finally agreed upon between the parties.

Occasionally, a party will desire to get out of an interference in which he is being purposely held by his opponent and he is willing to make sacrifices but does not wish to concede priority to his opponent. It may be that the party who wishes to get out of the interference is the first and original inventor as shown by the records of the Patent Office. If he wants to get out of the interference badly enough he may file a written disclaimer, in which case he leaves open the question as to who is the inventor or he may also file a written declaration of abandonment of the invention. In the latter case, he in effect is asserting that he is the real inventor, but that he abandons the invention to the public. In this case, nobody gets a patent. The reason for taking this step is that his opponent might by technical tactics hold the senior party up in the Patent Office for years and prevent the issuance of his patent until the commercial field has been exhausted, and he may decide it best to give up some unimportant feature of his invention and get his patent on the remainder thereof which is not involved rather than be held up indefinitely without getting anything.

Summary of Prime Movers Report on Pulverized Fuel

THE recently organized Edison Electric Institute has just issued a report of the Primer Movers Committee of the former National Electric Light Association entitled "Pulverized Fuel 1932–1933." It is gratifying to note that the Edison Electric Institute apparently intends to continue the publication of the excellent reports which the Prime Movers Committee of the old association has been issuing annually for many years past.

The pulverized fuel report for this year contains much valuable data. In the introductory section of it there is included a table of design and operating data of pulverized fuel installations in 48 stations. Detailed information is given on such major equipment as boilers, superheaters, reheaters, economizers, air heaters, furnaces, burners and pulverizing equipment. These equipment data are supplemented by fuel analyses and various operating figures. B.t.u. liberation is given per cu. ft. of furnace volume and building area and per sq. ft. of furnace cross section. Under "Annual Operating Values" are given such data as average evaporation per active boiler hour, per cent of rated maximum evaporation per active boiler hours, average total active boiler hours per boiler, total coal pulverized in short tons, total pulverizer operating hours, tons of coal burned per operating hour, total kilowatt hours consumed by pulverizing and transport equipment per ton of coal burned, operating labor (man hours per ton of coal pulverized for mill and transport attendants), and average B.t.u. liberated per cu. ft. of furnace volume per boiler active hour.

A second table gives annual operating data on power input for pulverizer systems, covering both direct and bin systems, for 24 stations.

There are statements* from fourteen operating companies giving their experiences with both bin and direct-fired systems and covering such points as operating experience, maintenance and performance both for the complete installations and particular items of equipment.

There are six statements of manufacturers of pulverized fuel equipment and one covering a process for the utilization of fly ash in the manufacture of building brick.

The statement by the Babcock & Wilcox Company covers new development with respect to both high capacity and low capacity pulverizers, particular reference being made to the 50 ton pulverizer installed at the Kips Bay Station of the New York Steam Corporation. Other items of this statement are grindability standards, burner developments with particular reference to a new burner suitable for coal, oil or gas either separately or in combination, lighting torches, Bailey Slag Tap Furnaces, vertical turbulent firing and the Bailey Stud-Tube Wall. A table is included showing recent grindability tests on various coals.

A statement by Combustion Engineering Corporation discusses the reliability of modern boiler units as exemplified by its installations at the East River Station of the New York Edison Company, Lakeside Station of The Milwaukee Electric Railway & Light Company, and the Kips Bay Station of the New York Steam Corporation. Recent developments with respect to burners and pulverizers are reviewed. In the case of burners particular reference is made to combination coal and oil burners as installed at the Burlington Station of the Public Service Electric and Gas Company and to a new type of horizontal burner for burning coal and oil or gas in combination either by natural or forced draft. The remainder of this statement relates to operating results obtained at the Kips Bay Station of the New York Steam Corporation, the Rouge Plant of the Ford Motor Company, the Springdale Plant of the West Penn Power Company and the Lincoln Station of the Boston Elevated Railway Company.

A statement by the Erie City Iron Works relates particularly to the company's recently completed installation at the plant of the Endicott-Johnson Corporation, Endicott, N. Y. Specific references are made to the Seymour Basket Furnace, Erie City Blatter Burners and the pulverizers installed at this plant.

A statement by the Foster Wheeler Corporation is devoted principally to a description of the development of the Hardinge Conical Ball Mill and its accessories into a firing system which can meet load changes without lag. The various new and improved features of the mill which have contributed to this operating result are described in detail. There are also descriptions of a new type of feeder for storage system installations, of inter-tube type and rotary turbulent type burners, and of a slag floor construction.

A statement by the Riley Stoker Corporation describes the new design of the Riley Atrita Unit Pulverizer, in which the pulverizing and fan chambers are combined in an integral housing of welded steel construction, and other improvements and changes in the design of this mill. References are made to the company's equipment and its performance in installations at the Kneeland Street Station of the Edison Electric Illuminating Company of Boston, the Champion Coated Paper Company, the Stamford Gas and Electric Company, and the West Virginia Pulp and Paper Company. A paragraph is devoted to a new burner known as the Riley Cyclone Burner which was developed to give higher coal burning rates.

A statement by Rostone Inc. discusses the problem of fly ash disposal and describes the development of a process for the utilization of fly ash. It is stated that progress has reached a point where fly ash can now be used commercially in the manufacture of brick and it also has possible uses in colored floor units. The process described is said to be adaptable to fly ash collected by both the Cottrell and sluice methods.

A statement by the Whiting Corporation describes improvements in the design of the Bethlehem Table Roller Pulverizer. These improvements relate particularly to method of lubrication, seals against dirt contamination, a device for taking rolls out of service while the pulverizer continues in operation and an air-control ring adjustable from the outside of the pulverizer.

The following statement by the Prime Movers Committee serves as the introduction to this report.

1. Direct or Bin System

Forty-three operating companies have reported on a total number of 181 boiler units having an aggregate steaming capacity of 55,000,000 lb. per hr. Of these, 16 have reported on boilers served by the bin system and 24 on boilers that are direct fired. Three companies are using both systems. Of the 181 boiler units 72, with a steaming capacity of 21,000,000 lb. per hr., are served by the bin system and 109, with a steaming capacity of 34,000,000 lb. per hr., are direct fired. These figures, tabulated here, show the average capacity of the direct fired units (315,500 lb. per hr.) to be somewhat larger than that of the bin system units (293,500 lb. per hr.).

* These statements are commented upon in the Committee's statement which is published as the conclusion of this review.

	Total Reported	Direct Fired	Bin System
No. of boiler units	181	109	72
Aggregate steaming cap. 1000 lb. per hr.	55,514	34,392	21,122
Steam cap. per blr.	306,700	315,500	293,500
Number of mills	367	253	114
Steaming cap. per mill	151,200	136,000	184,900

The trend seems to favor the direct fired system.

The methods of pulverizing and burning coal have made great advancement in the last five or six years and, during this period, each system has taken advantage of the improvements made in the other until today they both use much of the same equipment. This statement is partially illustrated by a recent bin system installation of the Public Service Electric and Gas Co., at Burlington, N. J., which utilizes much less pulverized coal storage capacity than is usually provided for this type of system. Advocates of both systems now realize that boiler efficiency is not a function of the system of firing used. If the pulverized coal has been equally well prepared, as it should be where two systems are using the same type of pulverizer, the boiler and furnace efficiencies can easily be the same. Coal and air streams must contain the right proportions of coal and air, through relatively narrow limits, to be explosive. It is the problem of the designers and operators to see that this condition is produced as infrequently as possible.

Mr. C. F. Hirshfeld, in a paper "Performance of Modern Steam Generating Units," presented at the December, 1932 Meeting of the A.S.M.E. in New York, gave the following Table as the result of an investigation of 250 units in 61 stations, during the three-year period between July 1, 1928 and July 1, 1931.

Comparison of Availability Factors of Pulverized Fuel Fired Units of the Unit and Storage Types

Type	Total Hours Reported	Crippled Hours	Crippled Hours Not Directly Chargeable	Net Cripple Hours	Availability Factor
Unit	234,113	36,198	25,833	10,365	0.955
Storage	828,153	112,887	78,112	34,775	0.958

Note that the availability factor for both systems is practically the same, both being over 0.95.

The Milwaukee Electric Railway and Light Co., in its report, has included a description of the method of comparison which it applied in arriving at its choice of firing system for the Port Washington Station. While some engineers may disagree with its conclusions, the description of the manner in which it attacked the problem is very instructive and suggests a basis for other comparisons.

Table I* gives design and operating data on recently installed pulverized fuel boiler and furnace equipments.

Table II* lists power consumption data grouped under the headings Direct and Bin Systems.

2. Coal Feed Interruptions

Many operating companies are experiencing trouble in feeding wet coal. Some of them have increased the slopes in their bunkers and coal chutes. The Buffalo General Electric Company shows the details of a new design raw coal feeder which cured that company's trouble. The Detroit Edison Company changed the design of a screw in the pulverized coal feeder to make it more dependable for light load operation.

3. Operation and Maintenance

Under this topic the majority of the companies submitting statements have reported on the life of mill parts and have specified them in the order of their importance in affecting cost of repairs and mill outage.

The Buffalo General Electric Company, with the direct fired system, has been able to operate boilers continuously at less than 12 per cent of their rated capacity.

The Detroit Edison Company has been able to improve the overall boiler room efficiency of its Trenton Channel Station by making slight changes in the equipment, which permits operating the boilers at very low rates of steaming.

The Montaup Electric Company, while burning chiefly fuel oil, has found it advantageous to burn pulverized coal several hours per week to prevent plugging of preheater tubes.

The Oklahoma Gas & Electric Company has submitted a very instructive report on operation and maintenance at Horseshoe Lake Station, where either petroleum coke or slack coal is burned, depending on market prices. Comparative curves of boiler and mill performance are included to show the results obtained when firing each of these fuels. Additional curves show the effect on fineness, of moisture, quantity of primary air, mill wear and mill loading.

As a result of experience with pulverizing and burning 10 per cent of coke breeze mixed with steam coal, the Stamford Gas & Electric Company is installing a chain grate stoker to burn coke breeze.

* Tables referred to in second and third paragraphs of this review.

4. Mill Performance

An increased knowledge of the requisites of efficient firing has been accompanied by an increasing demand for better mill performance. Many stations have conducted detailed tests to determine the principal factors affecting fineness of grinding and mill power consumption, with resulting conclusions agreeing in most respects.

It seems to be generally agreed that fineness of grinding of all types of mills, and particularly the attrition type, is appreciably affected by the quantity of air passing through the mill; fineness decreasing as air supply is increased. Where mills must be operated at various ratings to meet changing load conditions, the problem of regulating air supply to aid in obtaining uniform, satisfactory fineness becomes a difficult one. This is because other factors are introduced, such as: First, time required to dry the coal in the mill; second, pressures required at the burners to produce the proper turbulence, and third, quick response to load changes. Tests conducted at Hell Gate Station on the 10 ton, Type "B" mills, operating under pressure, have shown that at least three air flow settings are necessary to give satisfactory, uniform fineness from minimum to maximum rate of grinding. On impact mills at this same station, the fineness is not as good at low as at higher rates of grinding, because of the relatively greater ratio of primary air to coal at the low ratings.

Difficulties in effecting sufficient mill air regulation at most plants point to the requirement of improved means of classification which will separate the coarse coal from the fines and return the former for regrinding. A prominent ball mill manufacturer has made progress in this direction and has reported in some detail in this publication.

Most companies reporting on mill performance state that moisture in excess of a certain percentage decreases fineness and reduces mill capacity. The limits beyond which the moisture becomes excessive appear to be dependent, to a large extent, on the efficiency and extent of coal drying attainable in their respective mills. On the other hand, the Detroit Edison Company has reported that extreme dryness of coal will decrease the fineness of pulverization in their mills.

The Jersey Central Light & Power Co. prefers to operate ball mills with a very small amount of coal in them, making as much use as possible of the impact principle, whereas the Public Service Co. of Northern Illinois prefers to operate its ball mills with a large amount of coal in them at all times, thus making the most use of the attrition principle for pulverization. In the former case the coal represents only 3 to 4 per cent, whereas in the latter it represents 20 to 25 per cent of the mill charge.

Mill performance curves are reported, showing how fineness of pulverization varies with the rate of grinding, and also how it falls off in the impact type of mills with wear of the parts. Attrition and impact occur to a greater or less degree in all mills, although they are classified as: Attrition, Impact or Ball Mills.

Some companies report that it is more important that there be no 50 mesh than it is to have a very large percentage of 200 mesh coal. Other companies still contend that a large percentage of super-fines are desirable. Tests will be necessary to clarify this point.

5. Mill Drying and Dust Removal

Mill drying, accomplished by directly introducing either preheated air or hot flue gases into the pulverizer, is becoming more and more important in pulverizing coal in both the bin and unit systems of firing. Several companies which have described successful mill drying results in previous reports have remarked about their continued satisfaction with this method of drying.

In the bin system section of its Cahokia Station, the Union Electric Light & Power Company has eliminated coal fires in separately fired driers by the use of mill drying with flue gases.

Interesting developments in the fly ash collection and disposal field have been reported in detail by Rostone Incorporated, a research laboratory, working in conjunction with the Chemical Department of Purdue University. This company has developed a process for the fabrication of building brick from the fly ash of pulverized fuel burning installations.

6. Furnace Bottoms

The slag tap type of furnace bottom, which was developed by the Buffalo General Electric and the Babcock & Wilcox Companies in 1926, continues to be popular with operating companies. One manufacturer alone, has furnished, or has on order, seventy-six units with slag tap bottoms. The advantages of this type of bottom were listed on page 28 of N.E.L.A. Report No. 148 (Pulverized Fuel) published in August, 1931.

The Ohio Power Company has reported an average of 7300 hr. of service, at 225,000 lb. of steam per hr., on two direct fired, 2400 hp., 725-lb. boilers, equipped with "Plastic KN" (chrome ore)

(*Continued on page 34*)

Blackburn Meadows —Sheffield's New Power Station*

The Blackburn Meadows Station, placed in service in April of this year, is fairly typical of contemporary English practice which seems to be consistently in the direction of moderately high pressures (600-lb. range) and high superheat temperature. Boiler sizes and ratings continue to be conservative as compared to recent American practice in large stations. . . . At Blackburn Meadows, the boilers are designed for 625 lb. pressure and 800 fahr. total steam temperature. Their capacity is designated as 125,000 lb. of steam per hr. normal, and 156,000 lb. maximum. They are equipped with both air preheaters and economizers and are fired by traveling grate stokers. . . . This article presents a detailed description of the boiler and turbine equipment and principal auxiliaries.

SITUATED in one of the most concentrated industrial areas in the world, and certainly in England, the new power station at Blackburn Meadows has been opened at Sheffield to supply the ever-increasing demands for electricity and power in this district. In 1903 the capacity of the plant was 5125 kw.; the figure has increased to 131,000 kw. in the 30 years from that date, the latter figure, of course, being inclusive of the capacity of the new plant. In the same period the number of consumers increased from 2100 to 112,000 and the total units sold from 2,919,722 to 222,000,000. The authorized area of the Sheffield Electricity Department has a total of 78 sq. mi. and is one of the largest municipal areas in the country, serving a population of about 530,000 people.

The new station is designed for an ultimate capacity of 100,000 kw. The present buildings will accommodate plant of 50,000 kw. capacity; at the time of the opening, on April 6, last, a single 25,000-kw. turbo-generator had been installed.

Boiler Equipment

In this first section of the Blackburn Meadows station, three water-tube boilers have been installed. These units follow contemporary practice in England and are of comparatively moderate size. Their individual normal rating is 125,000 lb. and the maximum rating 156,000 lb. per hr., corresponding to 7.74 and 9.66 lb. per sq. ft. per hour.

As a point of fact the largest boilers at present installed in England are those at the Battersea Power Station of the London Power Company, which have an individual maximum capacity of 330,000 lb. of steam per hr. These are fired by multiple retort stokers. The next largest units are the Stirling type pulverized-fuel-fired boilers at the Ironbridge station which have a maximum capacity of 270,000 lb. per hr.

The boilers at Blackburn Meadows are designed to produce steam at 625 lb. per sq. in. and at a total temperature of 800 fahr. They are of the Stirling type, 47 tubes wide and 19 deep. The heating surface is 16,168 sq. ft. and the volume of the combustion chamber is approximately 8000 cu. ft. The combustion chamber, as shown in the illustration, is fitted with side walls of Bailey construction, refractory-faced blocks being employed. The heating surface given is exclusive of these water-cooled walls.

The drums are of forged construction with dimensions as follows: front drum 42 in. inside diameter, $2^1/_4$ in. shell, rear drum 48 in. dia., 3 in. shell and the mud drum 48 in. inside dia., $2^9/_{16}$ in. shell.

A superheater of the M.L.S. type is fitted to each unit between the front and second banks of tubes, each superheater having 4980 sq. ft. of heating surface. There are 88 tubes to each unit, the tubes being $1^5/_8$ in. in diameter.

The mechanical stokers are of the "L" type manufactured by Messrs. Underfeed Stoker Co., one to each boiler, the grate being 20 ft. long × 25 ft. wide, giving a total area of 500 sq. ft. per boiler. These stokers operate with preheated air and are each capable of burning 9.3 tons of coal per hour at maximum load.

Each boiler is fitted with a steaming economizer of the Foster gilled-tube type. In this economizer the tubes are of steel and are fitted with cast-iron gills. Each unit has 154 tubes, 2-in. outside dia. and 18 ft. 3 in. long with a total heating surface of 8316 sq. ft. The economizer is designed to reduce the temperature of the gases from 700 to 506 fahr. at normal load and raise the water from the feed temperature of 350 fahr. to a temperature of 421 fahr.

Immediately below the economizer an "S" type Usco plate air heater is installed in two sections having 220 elements 9 ft. 6 in. long, giving a total heating surface of 18,810 sq. ft. A by-pass is arranged between the economizer and the air heater so that the gases can be taken directly to the chimney at will. The air heaters are designed to reduce the gases from approximately 500 fahr. to 265 fahr. at normal load.

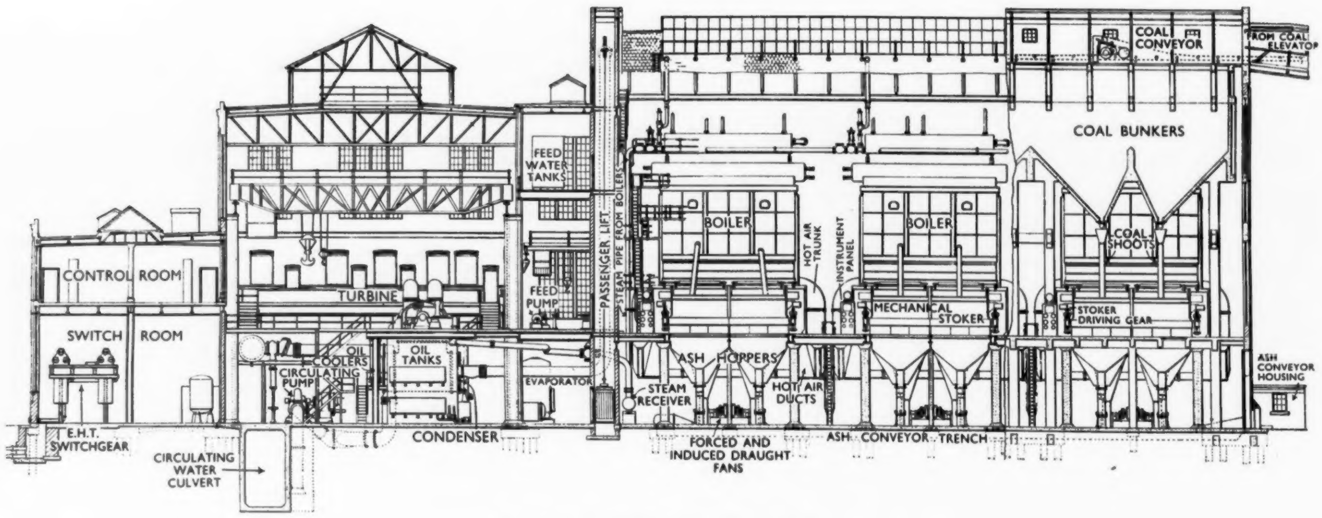
In order to prevent corrosion of the air heater elements, part of the hot air is recirculated, enough being taken from the main hot air duct to increase the temperature from about 60 fahr. (temperature at entrance to fan) to approximately 110 fahr. at the air heaters.

The gases from the boiler are drawn through the economizer and air heater by a single induced draft fan, motor driven and discharged into a Davidson dust collector from which they pass to a steel chimney. The induced draft fan motors run at a constant speed of 730 r.p.m., speed control being effected in the same manner as the forced draft fans, through a hydraulic coupling.

The fans are designed for handling approximately 105,000 cu. ft. of gas per min., at a temperature of 280 fahr. against $6^3/_4$ in. water gage; each fan is driven by a 260 hp. motor.

There are two forced draft fans for each boiler driven by a 115 hp. common motor situated between them, the drive being

* Contributed by an English correspondent.



Sectional elevation of station

through hydraulic couplings. The two fans are capable of 64,000 cu. ft. per hr. against a pressure of $5^1/_2$ in. water gage at 960 r.p.m.

A steel chimney of the self-supporting type, 144 ft. high by 9 ft. 6 in. dia., is provided for each boiler.

Secondary air is introduced above the fire bed by means of a steel duct, fitted with nozzles, which extends the full width of the boiler.

The guaranteed efficiencies for these boilers are based on the net or lower calorific value, although at the present time the use of the gross calorific value is becoming more general in England. The figures of the lower calorific value are 89.4 per cent at three-quarters load, 89.3 per cent at normal load and 88.3 per cent at the maximum load. The corresponding figures on the gross calorific value would be roughly 4 per cent lower than those given.

Boiler Instruments

A complete instrument panel is provided for each boiler. The instruments include a multiple type draft and pressure indicator, a steam flow to air ratio indicator of the circular, sector-scale type, electrically operated, steam flow and steam pressure meters, steam, feedwater and flue gas temperature recorders, fan motor ammeters, etc. In addition to this instrument equipment, a central control panel is also provided carrying continuous integrators totaling the steam evaporated by all three boilers. The instantaneous rate of flow of the total boiler feedwater is also shown. A multiple, continuous-strip-chart recorder provides continuous records of steam flow and feedwater flow in different colored inks. A recorder of a similar type gives the percentage of CO_2 in the flue gases from all three boilers, and a multiple, continuous-strip-chart temperature recorder with plug-selector switch-box gives records of selected temperatures as may be required.

Separate Kent boiler feed meters of the Venturi tube type are installed, each of which is capable of a maximum discharge of 200,000 lb. per hr. These three Venturi tubes are connected to one common recorder and each circuit can be connected in turn to a three-way switch board.

Apart from the weighing of the coal as it comes into the station, volumetric coal meters of the Lea recorder type are installed on each traveling grate stoker, so that coal entering each furnace is checked from day to day.

Coal Handling Plant

Coal is brought by rail to the plant siding where the cars are dumped mechanically into a hopper below the tracks. From here it is taken by skip hoists to an overhead hopper from which it is distributed by a belt conveyor to the bunkers above the boilers. The motor driving the conveyor is electrically interlocked with the motors driving the skip hoist and the feed tables under the track hopper, so that if it should be necessary to stop the conveyor suddenly, the other operations cease automatically. The electrical interlocking arrangement also provides for the proper sequence in starting.

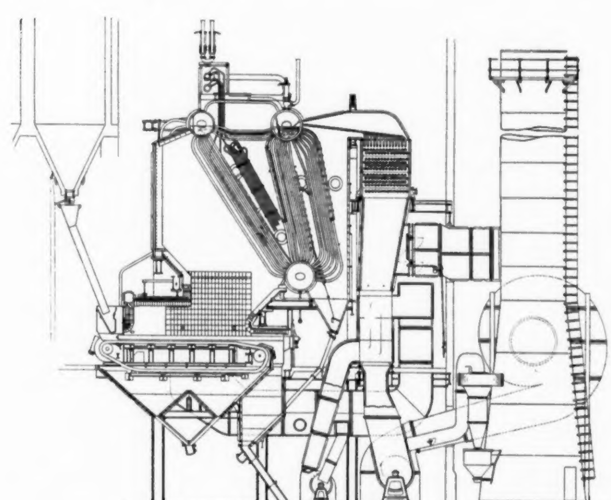
The weighing machines are integral with the tippler mechanism and are fitted with a ticket printing device which records all weights. The normal coal storage capacity is 13,000 tons but this can be increased in an emergency to 21,000 tons. The capacity of the coal bunkers for the existing three boilers is 1600 tons.

Ash Handling Plant

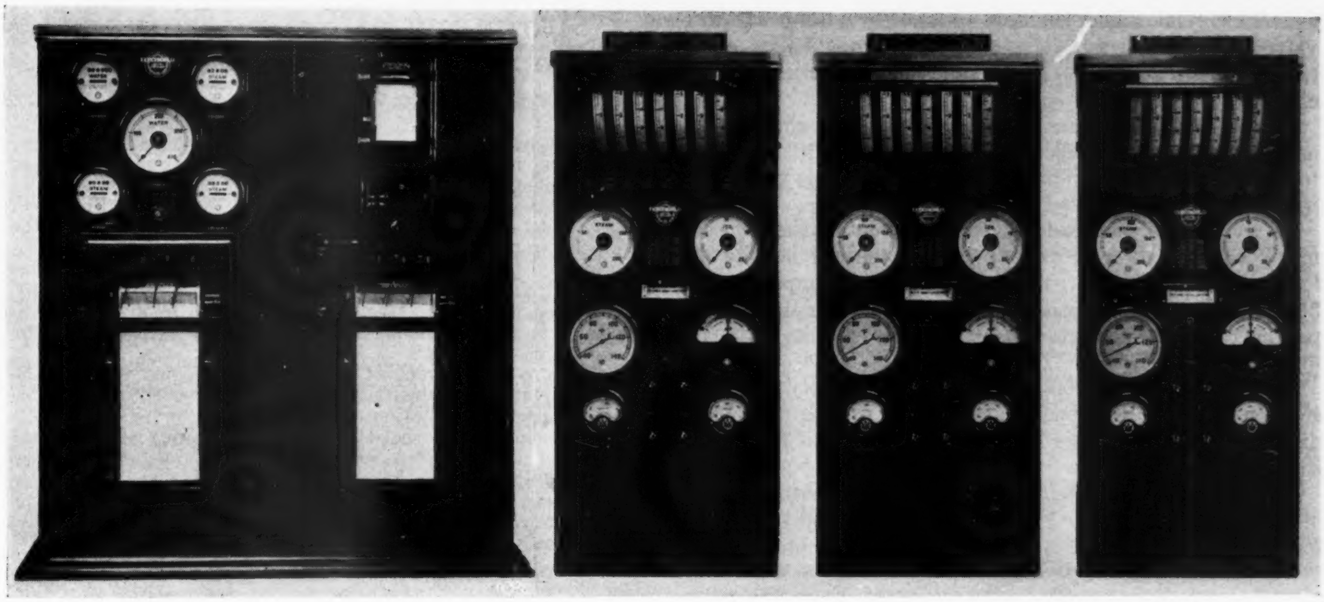
Two scraper conveyors of the water immersed type are provided in a basement below the boilers. The first receives the ash from the hoppers beneath the stokers and discharges it into a second similar conveyor outside the boiler house by which it is eventually discharged to a sump. The ash is removed from the sump by an automatic grab transporter which discharges into a reinforced concrete hopper capable of holding 40 tons of wet ash. After the water has drained away, the ash can be removed by an existing telpher and dumped on the site, or else by railway cars passing beneath the telpher gantry.

The ash plant is designed for a capacity of 16 tons per hour but its duty will only be in the neighborhood of 4 tons per hour with the plant as installed at present.

An interesting feature is that the removal of the ash by the



Sectional elevation of boiler, furnace and auxiliaries



Boiler control panels, central control panel on left and individual boiler panels on right

grab transporter is entirely automatic, the grab lowering into the sump, picking up its load, hoisting, waiting to allow the water to drain, traversing and discharging all automatically until stopped by a push button.

Fine ash and riddlings through the grates are removed from separate hoppers beneath the grates by cars.

Generating Plant

The turbine is a three-cylinder tandem unit consisting of a high-pressure casing and an intermediate casing, both having impulse blading, and a double-flow low-pressure casing with reaction blading.

Steam enters the turbine stop valve at a pressure of 570 lb. per sq. in. gage and a total temperature of 770 fahr. and exhausts into twin surface condensers. The steam enters the high-pressure casing by way of a separator, a main stop valve and throttle valve, passes from this casing to the intermediate casing through a pipe underneath the turbine floor, and then flows to the low-pressure casing through two overhead pipes. The low-pressure portion consists of a casing arranged on the double-flow principle so that steam enters at the center and flows in opposite directions toward the exhaust ends and twin condensers.

The high-pressure rotor carries fourteen impulse stages, the intermediate rotor nine impulse stages and each flow of the low-pressure rotor ten reaction stages. Although the design of the rotors is such that they are to some extent axially balanced, provision is nevertheless made to receive any end thrust by the incorporation of Michell thrusts at suitable points. Couplings of the flexible type are fitted between adjacent rotors as well as between the turbine and the generator. The main oil pump is of the gear type and is driven from the steam end of the high-pressure rotor through worm gearing and an auxiliary pump of the centrifugal vertical-spindle type driven by a small steam turbine. The latter is brought into action automatically by an oil relay when the oil pressure falls below a certain value.

The throttle valve is actuated in the usual way from oil relays controlled from the governor and pilot valve. The main throttle valve governs the turbine directly up to approximately

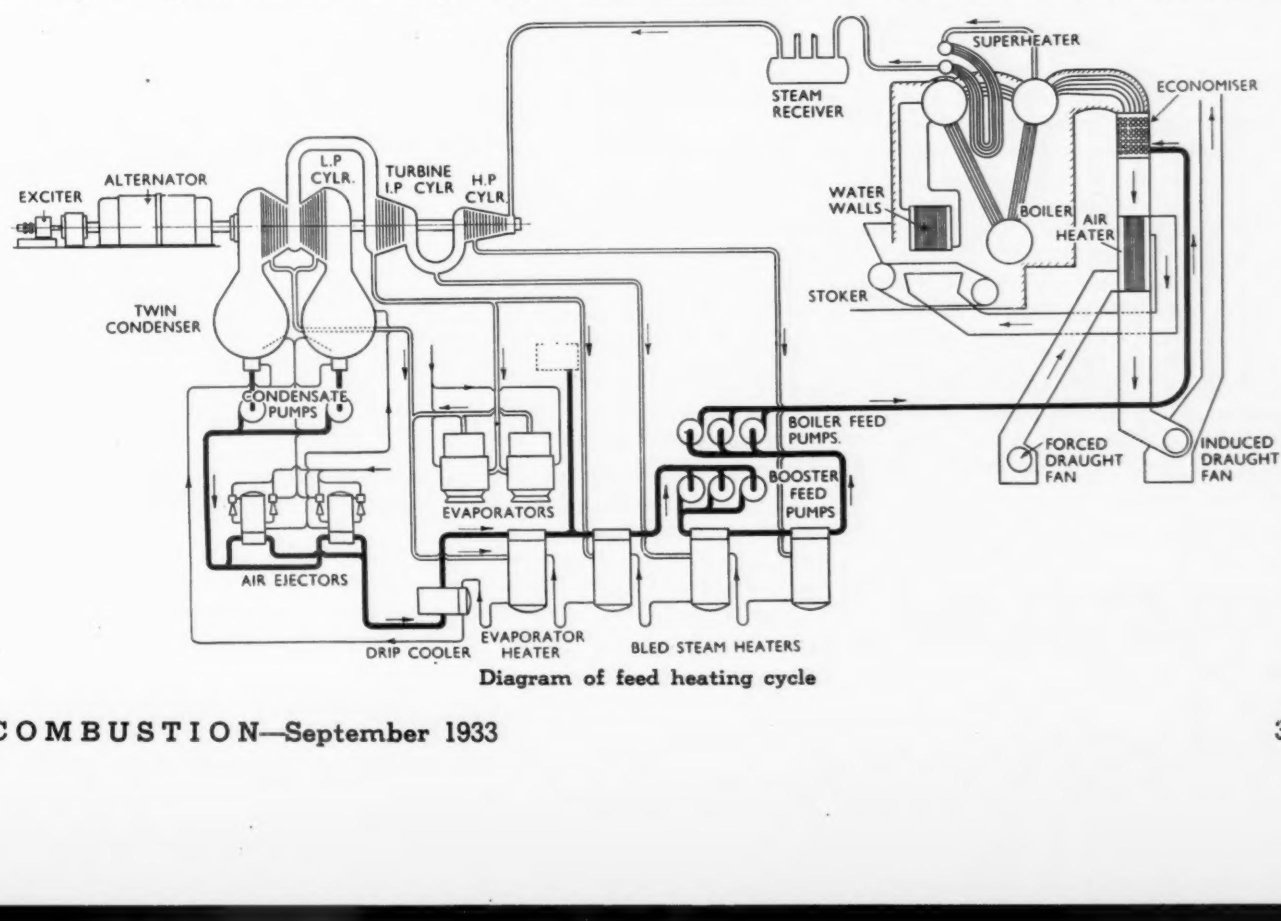


Diagram of feed heating cycle

18,000 kw. The higher loads are obtained by a full-load nozzle valve and two overload valves which are brought into operation by further movement of the throttle valve acting through oil-operated relays.

An emergency governor of the out-of-balance ring type is mounted on the turbine shaft and if this comes into action due to overspeed, or if the oil pressure fails, the throttle valves and main stop valve are closed automatically.

A carefully designed feed system insures that maximum use is made of feed heating by steam bled from the turbine, and the feedwater is heated up by this means to a final temperature of 350 fahr. at the economical load of the set. Make-up water is provided by two evaporators, each having a capacity of 10,000 lb. per hr.

Of the three sets of booster and feed pumps two sets are electrically driven and one steam driven; each is capable of discharging 25,000 gal. per hr. against a pressure of 730 lb. per sq. in.

The turbine drives an alternating-current generator capable of giving a maximum continuous output of 25,000 kw. in the form of 3-phase current at 50 cycles and of 11,000 to 11,400 volts, the power factor being 0.8. This machine is conservatively rated, and tests on similar alternators of English electric manufacture indicate that the actual temperature rises under service conditions will be lower than those guaranteed.

The generator is ventilated on the closed-circuit principle; air is forced through the machine by an external motor-driven fan at the rate of about 75,000 cu. ft. per min. and the heat is extracted in a cooler through which water is circulated. The cooling air enters at the ends as well as at the intermediate belts along the outside periphery of the stator core and tests have shown that this system results in a very high degree of uniformity in the temperature along the entire length of the machine.

The body of the rotor is formed from a solid carbon steel forging and suitable axial slots are machined to receive the winding and for ventilation purposes. The winding is secured in the slots by means of steel and bronze keys and the end portions are held together in the strongest possible way by retaining rings of special alloy steel. Metallic packings are placed between the end portions to improve the solidity of the mass, and to assist in heat conduction.

The condenser was supplied by the English Electric Co., Ltd., and is of the regenerative twin-shell type. It has a total cooling surface of 24,700 sq. ft. and is designed for handling 157,700 lb. of steam per hr. at a vacuum of 28.37 in. with a barometer at 30. It requires 1,746,000 gal. of water per hr. at 80 fahr., the total friction head on the water side being eight feet. The water circulates through cooling towers, but to make up any loss, effluent water, purified by chemical treatment, is obtained from an adjacent sewage disposal works.

The cooling towers are four in number and are of the natural-draft chimney type. Their dimensions are individually as follows: length 145 ft., width 38 ft., height 90 ft. The capacity of each unit is 500,000 gal. per hr., reduced from 100 to 79 fahr. with the air at 55 fahr. with a humidity of 75 per cent.

Two Drysdale condensate pumps of the centrifugal type are installed, each capable of 28,500 gal. per hour against a total head of 132 ft. Each is driven at 1460 r.p.m. by a 40-hp. motor. There are two Weir evaporators, of the surface type, each having a heating surface of 375 sq. ft. and a capacity of 10,000 lb. of water per hr. There are also two Mirrlees Watson air ejectors, of the steam-jet two-stage type, each having a capacity of 128 lb. of dry air per hr. with a steam pressure of 455 lb. per sq. in.

Mr. George Quint, for many years well known in the field of plastic refractory sales and installation, is now associated with the Refractories Division of The M. W. Kellogg Co., New York, N. Y.

Summary of Prime Movers Report on Pulverized Fuel

(*Continued from page 30*)

slag-tap furnace bottoms. The only repairs required were very minor ones, made at the tap holes. The water-cooled type of slag-tap bottom is working out satisfactorily in other stations.

Extensive experiments have been conducted by the Bureau of Mines, under the auspices of a special research committee of the A.S.M.E., to find a substance which will lower the fusion temperature of slag in order to increase the range of application of this type of furnace. Their findings were reported by P. Nicholls, at the December, 1931, Meeting of the A.S.M.E. in New York, in a paper entitled, "Fluxing of Ashes and Slags as Related to the Slagging Type Furnace."

Only one company reports that it is using a flux to lower the fusion temperature of their slag. Soda ash has been used for this purpose at Hell Gate Station.

There are indications that the problem of slagging when burning coals having ash fusion temperatures of 2500 to 2550 fahr. may be solved by improved burner design and flame direction. Buffalo General Electric Company reports slagging boilers in Charles R. Huntley Station No. 2 with less than 25 per cent of rated load when burning coal with ash fusion temperatures of 2240 fahr. The Bureau of Mines' tests on the same coal samples gave fusion values in excess of 2500 fahr.

7. *New Developments*

The light load periods of operation, of plants, such as those with hydroelectric ties, have called for greater flexibility of equipment, and many new developments and improvements in design appear to be in the manufacturers' statements.

Much attention is being given to the elimination of lag in pulverizing equipment, in an effort to make the latter as flexible as the unit which it serves.

Under Topic 2, many companies have discussed the need of raw coal feeders which will successfully handle wet coal. Others have expressed the desirability of a magnetic separator, for direct-fired, pressure-type mills, which will permit the removal of tramp iron without shutting off the coal feed.

The need for improved means of pulverized coal classification has been cited under Topic 4. There seems to be much room for improvement in so shaping the coal and air passages in mills and classifiers that coarse coal will settle out and the remaining coal pass on through the equipment without separating enroute to the furnace.

The developments outlined above entail an immense amount of experimentation, which will require close cooperation between manufacturers and operating companies. It is quite apparent that this cooperation can only be obtained by manufacturers from companies whose engineers have sufficiently visualized the gains to be desired and who then feel their participation warranted.

8. *Corrosion*

From the Operating Companies' Statements, pulverized fuel fired installations appear to be unusually free from corrosion in the flues, air heaters and gas ducts. At Charles R. Huntley Station No. 2, of the Buffalo General Electric Co., no noticeable corrosion or plugging of the regenerative type of air heater has developed in over two years of operation, at loads between 65,000 and 100,000 lb. of steam per hr., on boilers capable of delivering 600,000 lb. of steam per hr. each. This bears out the findings of Prof. Henry Fraser Johnstone, who states in University of Illinois Engineering Experiment Station Bulletin No. 228, that "corrosion in pulverized fuel systems is never severe, even when the same fuel produces corrosion when fired on a stoker."

The Milwaukee Electric Railway and Light Company, operating a bin system, has eliminated corrosion in another part of the plant in its insulated-steel pulverized coal bins by introducing enough 200 fahr. flue gas into the bins to reduce the relative humidity there to 50 per cent.

The Whiting Corporation, Harvey, Ill., announces that W. R. Wood has joined the sales staff of its Combustion Division.

Mr. Wood was for about 15 years connected with the Green Engineering Company and its successor, the Combustion Engineering Corporation, and has had extensive experience in the sale of stokers, boilers and pulverized coal equipment.

NEW EQUIPMENT

of interest to steam plant engineers

Observation Port

A recently developed observation port for observing furnace conditions in boilers and other types of furnaces has been announced by the Plibrico Jointless Firebrick Company, Chicago, Illinois.

The Plibrico Observation Port, shown in the accompanying illustration, is provided with a double cover consisting of an

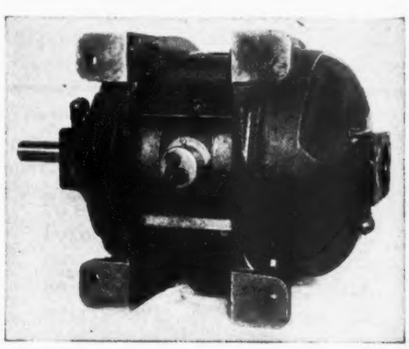
inner circular metal disk and the outer window cover. The inner cover lifts with a slight pressure on the handle and closes automatically the moment the handle is released by the operator. This arrangement makes it impossible for the operator to leave the port uncovered and thus allows an inrush of excess air. The overlapping sections of the cover close tight, practically eliminating any infiltration.

The outer cover of the port is equipped with a glass to protect the eyes of the operator from possible injury. This glass is made of blue Pyrex to resist the heat and diffuse the glare.

The Plibrico Observation Port is claimed to be both inexpensive and very efficient.

Thermostat Controlled Motors

Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania, have recently announced the "Thermoguard Motors." These motors have a



built-in disk thermostat that functions before the temperature of the insulation reaches the danger point.

Thermoguard motors are available in two types: one will be disconnected from the source of power when the temperature approaches the danger zone, and the other will give an audible or visible signal when an unsafe temperature is being approached.

On processes where an enforced motor shut-down would cause a loss of product or other hazard, the Thermoguard motor will give advance warning that an emergency exists—and corrective measures can be taken. When desirable, Thermoguard motors can be arranged to stop when their temperature is dangerously high and cannot be started until the operator manipulates the control. On unattended applications, it is possible to arrange the control so that the motor will automatically re-start when it has cooled to a safe operating temperature. The Thermoguard principle has been applied to induction, direct current, mill and high speed synchronous motors.

Automatic Oilers

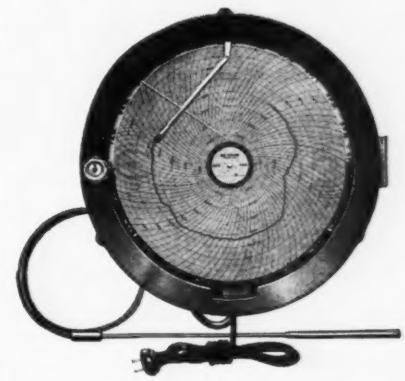
The Speedway Manufacturing Company, Cicero, Illinois, have announced a line of automatic oilers to be known as Speedway Oilers. These new oilers are of two types: "Constant Level" and "Thermal." The Constant Level Oilers are designed especially for use on electric motor bearings and other reservoir bearings with oil-ring, packing, ball or roller bearings where oil in the reservoir should be maintained at a determined level. The

automatic feature of this oiling device is obtained by means of a tube which permits air to enter and oil to flow from the oil reservoir when the level of oil in the reservoir drops below the fixed and proper level and automatically stopping the flow of oil when this level is attained. The Thermal Oilers, designed for use on sleeve bearings of the open type, are operated wholly by change in the bearing temperature. Heat in the bearing causes an expansion of the air in the thermal chamber, forcing small quantities of oil, just enough, to the bearing. Both types of Speedway Oilers have a visible oil supply.

New Recording Thermometer and Pressure Gage

An entirely new and improved line of 8-in. and 12-in. circular chart instruments has just been placed on the market by The Brown Instrument Company, Philadelphis, Pennsylvania. These instruments include indicating or recording thermometers for temperatures from 40 fahr. up to 1200 fahr., and indicating or recording pressure and vacuum gages for ranges from 10 in. of water up to 5000 lb. All types are offered in one, two or three pen models.

In developing this new thermometer line, much research was devoted to improving the helix mechanisms (Bourdon tubes). The mercury-filled helix is built of a special stainless steel which stands 100 per cent overload and provides a surplus of power to move the pen. The gas and vapor type helices are made of heat-treated phosphor bronze. These thermometers may be located at distances up to 200 ft.



An electric clock eliminating daily hand winding, is standard at no extra cost for all models. Where a.c. current is not available, hand-wound clocks are furnished.

Cases are of die cast non-corrosive aluminum and are interchangeable for back or bottom connection or for flush panel mounting, permitting unlimited flexibility in installation.

A great variety of sizes and shapes of bulbs are available. Also, a wide choice of standard charts is offered.

Other new features claimed, include: handy toggle switch to start and stop electric clock; combination door handle and built-in lock; automatic chart clips carried on door hold chart in place; no chart knob to lose—chart is simply pressed on chart hub; automatic pen release of powerful construction lifts pen from chart when door is opened; greatly increased torque eliminates pen friction; convenient micrometer thumb screw permits easy recalibration, if range of the instrument is to be changed after installation; felt gasket and cemented glass in door makes case dust and moisture-proof; zero adjuster is rugged and accessible.

Boiler Tubes

Jones & Laughlin Steel Corporation of Pittsburgh has announced a complete line of hot-rolled seamless steel boiler tubes. A push-bench mill, the only one of its kind in this country, is used for manufacture.

These J. & L. boiler tubes are claimed to have exceptional ductility and lend themselves quite readily to rolling in and beading operations. Both inside and outside surfaces of these tubes are very smooth, this being an important factor in retarding corrosion when the tubes are in use and in minimizing depreciation while they are held in stock.

NEW CATALOGS AND BULLETINS

Any of the following publications will be sent to you upon request. Address your request direct to the manufacturer and mention COMBUSTION Magazine

Electric Meters

Telemetering and Totalizing Station Loads is the title of bulletin No. 874, just issued by the Leeds & Northrup Company, 4901 Stenton Avenue, Philadelphia, Pa. This bulletin discusses means for providing the load dispatcher of an electric power system with continuous information on load conditions throughout the system, to facilitate load distribution in ordinary conditions, and to aid in control of emergencies. It describes apparatus for local recording of the outputs of generating units, stations and tie lines, for transmitting the records to the load dispatcher's office, and for combining them into the total for the system. 16 pages and cover, $8^1/_2 \times 11$.

Forced Draft Fans

A new bulletin has been recently published describing the Sturtevant Rexvane Forced Draft Fans. The new principles of fan construction embodied in this fan are explained very clearly. The bulletin includes photographic illustrations, tables, line illustrations and charts. $8^1/_2 \times 11$, 12 pages—B. F. Sturtevant Company, Hyde Park, Boston, Massachusetts.

Forged Steel Valves

A pamphlet has just been issued illustrating and briefly describing the various Edward Valves manufactured. 2 pages, $8^1/_2 \times 11$—The Edward Valve & Manufacturing Company, East Chicago, Indiana.

Industrial Motors

A pamphlet has been just published describing a new line of industrial motors. These power units are inherently electric motor driven speed reducers inasmuch as each incorporates a motor element and reduction spur gear trains. 4 pages, $8^1/_2 \times 11$—Minneapolis-Honeywell Regulator Company, 2710 Fourth Avenue, South, Minneapolis, Minnesota.

Metallizing Process

A catalog has recently been issued covering the Metallizing Process, its applications, advantages and its accessory equipment. The applications of this process cover each field, listing objects coated, type of metal used and the purpose of coating. This catalog is generously illustrated, having over fifty photographic reproductions showing different types of work done by various users. $8^1/_2 \times 11$, 20 pages—International Metallizing Association, 214 Provost Street, Jersey City, N. J.

Multiple Retort Stoker

A new catalog describing the Detroit Multiple Retort Stoker has been recently announced. This stoker is of the inclined fuel bed, underfeed type with a continuous movement of fuel under mechanical control. This catalog very comprehensively sets forth the design features and includes many illustrations of construction details and parts. 12 pages, $8^1/_2 \times 11$—Detroit Stoker Company, General Motors Building, Detroit, Michigan.

Oil Burners

Bulletin O-B 3-33, entitled Enco Burners, sets forth the principles of design of this burner and also describes the complete line of oil burning equipment, developed and manufactured by The Engineer Company. This equipment is built in a range of capacities sufficient for applications to boiler units up to 3000 hp. rating. This bulletin also includes tables, drawings and product and installation pictures. 12 pages, $8^1/_2 \times 11$—The Engineer Company, 17 Battery Place, New York City.

Pulverizing and Burning Equipment

Radiant Heat from Air Floated Pulverized Coal is the name of a recently published catalog. This catalog describes the construction and application of Kennedy-Van Saun Roller Mills, Burners, Crushers, Feeders and other equipment. It includes a brief treatise on pulverized fuel, as an introductory, many descriptions of Kennedy-Van Saun installations, photographs of products and installations, tables, curves and a comprehensive index. $8^1/_2 \times 11$, 84 pages and cover—Kennedy-Van Saun Manufacturing and Engineering Corporation, 2 Park Avenue, New York.

Pumps

Catalog H-32 describes the complete line of pumps manufactured and sold by the Rumsey Pump Company, Ltd., Seneca Falls, N. Y. This catalog is profusely illustrated and contains tables giving capacities, weights, horsepower of engine, list prices, etc. Valuable data relative to pumps is also included. 96 pages and cover, $8^1/_2 \times 11$.

Pyrometers

A pamphlet entitled Pyrometers has been issued by the Mishawaka Industrial Instrument Manufacturing Laboratory, 936 Washington Avenue, Mishawaka, Indiana. This pamphlet describes Mishawaka Pyrometers of the indicating thermo-electric type models No. 20, 30, 40 and 50. Illustrations, data and scale reproductions. 6 pages, 4×9.

Quiet Electric Motors

A pamphlet entitled G-E Quiet Induction Motors has been recently issued. This new motor has been specially designed and manufactured to practically eliminate the noise incident to the operation of electric motors. The squirrel-cage and wound-rotor type motors are available in capacities from $^1/_2$ to 50 hp.; the single-phase in capacities from $^1/_2$ to 10 hp. All three types are available in constant or adjustable-varying speed, and with standard speeds, voltages and frequencies. 4 pages, $8^1/_2 \times 11$—General Electric Company, Schenectady, New York.

Rubber Belt Treatment

"Lubricated with Rubber" is the title of a pamphlet recently issued. The wearing characteristics of rubber belts are discussed with a view to the application of this newly developed rubber belting compound. 8 pages, $6^1/_2 \times 6^1/_2$—The B. F. Goodrich Rubber Company, Akron, Ohio.

Steam Trap

Bulletin No. 528-A describes the design, construction and application of the Nicholson Weight Operated Trap for steam, air or gas. These traps are suitable for pressures up to 450 lb. per sq. in. 4 pages, $8^1/_2 \times 11$—W. H. Nicholson & Company, 12 Oregon Street, Wilkes-Barre, Pennsylvania.

Two Stage Air-Cooled Portable Compressors

A large comprehensive catalog has been published describing and illustrating the new Ingersoll-Rand Two Stage Air-Cooled Portable Compressors. This new compressor is claimed to have many new features which are clearly described. This catalog is profusely illustrated with photographic reproductions and diagrams. Tables of data, etc., 36 pages and cover, $8^1/_2 \times 11$—Ingersoll-Rand Company, 11 Broadway, New York.

Welding

A new bulletin has been issued describing G-E Atomic-Hydrogen Arc-Welding Equipment. This bulletin very comprehensively sets forth the principle of atomic-hydrogen arc-welding, its general and specific fields of application, its advantages and other data. It includes many illustrations. 8 pages, $8^1/_2 \times 11$—General Electric Company, Schenectady, New York.

NOTICE

Manufacturers are requested to send copies of their new catalogs and bulletins for review on this page. Address copies of your new literature to

COMBUSTION
200 Madison Ave., New York

REVIEW OF NEW TECHNICAL BOOKS

Any of the books reviewed on this page may be secured from In-Ce-Co Publishing Corporation, 200 Madison Avenue, New York

American Society of Heating and Ventilating Engineers Guide, 1933 (11th Edition)

THE 11th annual edition of this standard reference volume on heating, ventilating and air conditioning has been extensively enlarged and revised to include the latest results of research and modern engineering practice. The Guide 1933 embodies in its 45 chapters not only data developed at the A.S.H.V.E. Research Laboratory and cooperating institutions, but also the most practical and useful ideas of outstanding engineers in the profession.

The text of Chapter 3, dealing with transmission losses, is new and contains a set of completely revised tables with coefficients of transmission based upon the latest results obtained at the Research Laboratory of the Society in Pittsburgh and at the Experimental Engineering Laboratories of the University of Minnesota. More up-to-date information on heating boilers appears in Chapter 14. Important additions have been made in Chapter 22 dealing with ventilation and air conditioning standards for comfort and health. The new Ventilation Standards, adopted in 1932, are included.

Central Fan Air Conditioning Systems are treated in Chapters 24 and 25, which contain considerable heretofore unpublished information. The material on the design of air ducts (Chapter 33) has been amplified by introducing new and more complete examples showing the methods of determining accurate sizes. In Chapter 39, the section dealing with Test Instruments and Methods is largely new. Chapter 36, on Natural Ventilation, is new, and extensive changes have been made in Chapter 38, devoted to Fans and Motive Power.

The 592 pages of text matter in The Guide are supplemented by the valuable Catalog Data Section of Modern Equipment, in which detailed descriptions, sizes, capacities and dimensions of manufacturers' products are given.

The Guide is 6 × 9 in. in size, bound in a handsome red fabrikoid cover stamped in gold. Price $5.00.

Heat Transmission

By William H. McAdams

THIS book, which is sponsored by the Committee on Heat Transmission of the National Research Council, is designed to serve both as a text for students and as a reference for practicing engineers. Fundamentals rather than details of individual problems and special cases are presented. It may be divided into three parts: conduction, radiation and convection.

The section on conduction consists of two chapters, the first dealing with steady conduction of heat, thermal conductivities, the effect of the shape of bodies, and resistances in series and in parallel. In the second chapter, unsteady conduction, as in the heating and cooling of solids, is considered, and problems are solved by the use of charts involving four dimensionless ratios.

The second section treats radiation between solids for a number of important specific cases, radiation from non-luminous and luminous flames, and the general problem of furnace design, where heat is transferred simultaneously by several mechanisms.

The third section consists of seven chapters. The first of these deals with dimensional similarity. Because of the important relation between fluid motion and forced convection, a chapter is devoted to fluid dynamics. The third chapter serves as an introduction to convection and treats the relations between over-all and individual coefficients of heat transfer, the effect of deposits of scale, mean temperature difference in heat exchangers involving counterflow, multipass and cross flow, and the measurement of surface temperatures.

The four remaining chapters deal with heat transfer by forced and free convection under the general headings of fluids inside pipes, fluids outside pipes, condensation, and evaporation. Photographs of convection currents, and charts of distribution of velocity and temperature, illustrate the mechanisms involved. The original data of a number of reliable investigators are plotted to develop the relations recommended for the various cases, and the experimental ranges of the various factors are tabulated. Optimum operating conditions are considered, and methods are given for determining the economic velocity of fluid in a heat exchanger and the optimum temperature difference in waste heat recovery.

The appendix contains tables and charts of thermal conductivities, specific heats, latent heats of vaporization, viscosities, steam tables and dimensions of steel pipe, and the bibliography contains over 500 carefully selected references.

The book contains 383 pages, including index, and is cloth bound. Its overall size is $5^3/_4$ × 9. Price $5.00.

The Engineer's Manual of English

By W. O. Sypherd and Sharon Brown

THE *Engineer's Manual of English* is a practical guide for all technical writing which the engineering student may need to do while in college and later on in connection with his professional duties.

The book is divided into two parts: "Engineering Writing" and "Specimens of Engineering Writing." The first part deals with the application of the principles of formal rhetoric to the actual problems of the engineer-writer. The second part comprises a complete collection of specimens of engineering writing.

The Manual is unique in its concentration upon those phases of writing essential to the engineering profession. No detail concerning the forms of technical writing is missing. Every step is carefully explained and fully illustrated. In this connection, in the Preface, the authors point out: "Throughout Part I the nature of the discussion and the selection of illustrations have been dictated by the desire to produce not an English Manual for engineers but an Engineer's Manual of English. In other words, this book is for the engineer-writer, graduate or undergraduate, and for him alone. It is written in his language, it deals with the concerns of his profession, it interprets the art of communication from his particular 'slant.'"

The book contains 526 pages, including index, size $4^1/_2$ × $6^1/_2$. Price $2.00.

ENGINEERING BOOKS

1—Bailey's Handbook of Universal Questions and Answers (Sixth Edition)

264 Pages $4^3/_4 \times 6^1/_2$ Price $2.00

The questions and answers contained in this Handbook are those that have been universally asked by examining boards and were compiled from over four hundred examination papers, including tests for firemen, engineers, and boiler inspectors. It gives information on the subject of boilers, pumps, fuel consumption, valves, heating systems, engines, etc., and will be of assistance not only to those studying for any grade of license in this country or in Canada but also to the practical engineer and fireman.

The author, A. R. Bailey, is intimately acquainted with the needs of practical engineers and firemen and of candidates for licenses, having served as engineer and boiler inspector in the states of Massachusetts, Ohio, Pennsylvania and Michigan, and as safety engineer for the Lincoln Motor Company, Detroit. The sixth edition of this book, recently published, has been brought thoroughly up to date.

2—Pulverized Fuel Firing

By Sydney H. North

204 Pages Illustrated Price $2.25

The author of this book, an Englishman, briefly reviews the history of pulverized fuel as a prelude to a discussion of its development to the present day. Contemporary designs of furnaces, burners, feeders, pulverizing mills, driers, dust collectors, etc., are described and illustrated, as are actual installations in America and Europe which exemplify the trends of practice. Chapters are devoted to the combustion of pulverized fuel and its use in connection with Lancashire boilers, marine boilers and in metallurgical furnaces.

3—A.S.T.M. Refractories Manual

93 Pages 6 x 9 Price 50 cents

This publication, issued by the American Society for Testing Materials, brings together in convenient form the several A. S. T. M. standard specifications, method of testing and definitions pertaining to refractories. It also includes the latest revision of the Manual for Interpretation of Refractory Test Data.

4—Draft and Capacity of Chimneys

By J. G. Mingle

339 pages Price $3.50

The most authoritative book ever published on the subject of draft and chimneys. The subject matter has been developed primarily from a theoretical standpoint and then amplified by experimental data gleaned from actual practice.

The author observes that draft, even to the expert, frequently contains an element of mystery, and that there is often a great deal of confusion and misconception on the subject. A careful study of this book will give a thorough and practical knowledge of this important subject.

The book is profusely illustrated with graphs and charts. Many valuable tables are included and the index has been prepared for ready reference.

5—Fan Engineering (Third Edition)

622 Pages $4^3/_8 \times 7$ Price $3.00

The Buffalo Forge Company, Buffalo, N. Y., has just issued the third edition of its book, Fan Engineering, which is a complete, up-to-date and reliable treatise on the theory and practice of fan applications for all purposes. As with the previous editions, most of the material contained is original, and many of the tables and charts are based on research done expressly for this publication.

The subject matter of the book has been divided into three parts, as follows:

Part I deals with the physical properties of air, heat and humidity, as well as the flow of air in general and as regards the fan in particular.

Part II relates to the application of air and air movements to the various classes of work for which fans may be adapted, such as heating, ventilation, humidifying and dehumidifying, cooling and refrigeration, drying, combustion and mechanical draft, dust elimination, etc.

Part III contains performance tables and general information concerning standard apparatus used in fan work.

Bibliographies at the end of each section furnish suggestions for collateral redaing. The appendix contains, in addition to the standard test code, 19 pages of miscellaneous and useful engineering data. A very comprehensive index, thoroughly cross-indexed, facilitates reference work.

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Book Nos. ....

6—Power Plant Management

By Walter N. Polakov

171 Pages Price $2.00

This book offers information of considerable value to those concerned with the management or supervision of power plants and will help to solve many problems.

Today, power plant cost comes next to payroll as an expense item in textile finishing, paper products, food industries and other enterprises. In the application of efficient methods—checking layouts, costs, waste, etc.—in the generation, distribution, and utilization of power, and especially in the scientific organization of the human element, savings of tens and hundreds of thousands of dollars are possible. It is to show management's place in creating these savings—to outline the simple proceedings necessary for the typical power plant, large or small—that this book was planned.

7—Steam Tables and Mollier Diagram

By Joseph H. Keenan

Price $2.00

These new Steam Tables, extending to a pressure of 3500 lb. per sq. in. and a temperature of 1000 deg. fahr., were developed from the latest experimental data secured by investigators in laboratories of Europe and those of the United States. The Symbols used in this work are taken from the latest test prepared by the A.S.A. Sub-Committee for Heat and Thermodynamics. A large copy of the new Mollier Diagram (23" x 34") is also included.

8—Finding and Stopping Waste in Modern Boiler Rooms

808 Pages Price $3.00

This well-known Cochrane reference book has been revised and enlarged. New matter has been introduced in the section on Fuels, Combustion and Heat Absorption, and considerable material has been added on the subjects of steam and water measurements, water treatment and testing. As a handbook on these subjects, this volume is eminently practical and useful. Every steam plant engineer should have a copy.

9—Water Analysis for Sanitary and Technical Purposes

By Herbert B. Stocks

135 Pages $3.50

Public health officers, city chemists and those engaged in the study of this branch of analytical work will be interested in this new edition of a book which has long been a standard in this country and England on the subject of the methods adopted for the analysis of water for sanitary and technical purposes. It has been completely revised, rearranged and added to by W. Gordon Carey.

Modern developments have necessitated new sections dealing with hydrogen-ion concentration, the determination of free chlorine in chlorinated water, and the determination of iodides. A section on simple bacteriological methods is included in this edition, and should prove of service to those who use this book.

EQUIPMENT SALES

Boiler, Stoker, Pulverized Fuel

As reported by equipment manufacturers of the Department of Commerce, Bureau of the Census.

Boiler Sales

Orders for 144 water tube and h.r.t. boilers were placed in July.

	Number	Square Feet
July, 1933	144	455,822
July, 1932	73	251,351
January to July (inclusive, 1933)	527	1,602,072
Same period, 1932	384	1,263,990

NEW ORDERS, BY KIND, PLACED IN JULY, 1932-1933

Kind	July, 1932 Number	July, 1932 Square Feet	July, 1933 Number	July, 1933 Square Feet
Stationary:				
Water tube	43	213,318	90	380,090
Horizontal return tubular	30	38,033	54	75,732
	73	251,351	144	455,822

Mechanical Stoker Sales

Orders for 172 stokers, Class 4,* totaling 41,249 hp. were placed in July by 42 manufacturers.

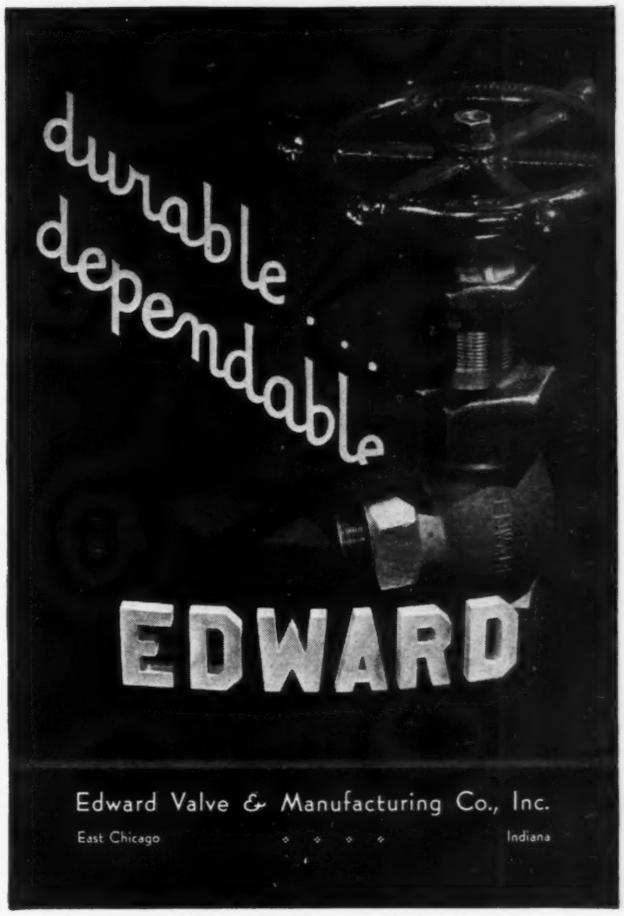
	Installed under			
	Fire-tube Boilers		Water-tube Boilers	
	No.	Horsepower	No.	Horsepower
July, 1933	105	14,337	67	26,912
July, 1932	70	8,605	44	16,463
January to July (inclusive, 1933)	470	62,614	241	88,080
Same period, 1932	449	59,568	229	94,279

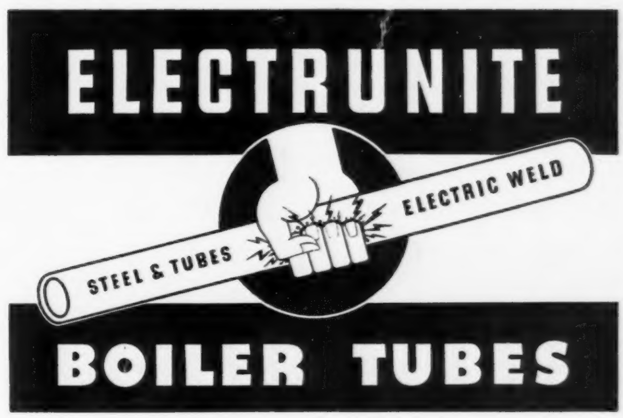
* Capacity over 300 lb. of coal per hr.

Pulverized Fuel Equipment Sales

Orders for 9 pulverizers with a total capacity of 92,600 lb. per hr. were placed in July.

	STORAGE SYSTEM						
	Pulverizers				Water-tube Boilers		
	Total number	No. for new boilers, furnaces and kilns	No. for existing boilers	Total capacity lb. coal per hour for contract	Number	Total sq. ft. steam-generating surface	Total lb. steam per hour equivalent
July, 1933	..	..	..	....	..	....	......
July, 1932	5	1	4	11,250	5	17,400	110,500
January to July (inclusive, 1933)	2	..	2	60,000	2	37,000	325,000
Same period, 1932	5	1	4	11,250	5	17,400	110,500
	DIRECT FIRED OR UNIT SYSTEM						
	Pulverizers				Water-tube Boilers		
July, 1933	9	9	..	92,600	8	69,733	829,600
July, 1932	7	3	4	18,250	7	24,900	173,010
January to July (inclusive, 1933)	43	32	11	252,840	35	244,406	2,312,960
Same period, 1932	47	30	17	225,588	43	223,986	2,041,460
					Fire-tube Boilers		
July, 1933	..	..	..	....	..	....	......
July, 1932	..	..	..	....	..	....	......
January to July (inclusive, 1933)	9	2	7	7,700	10	14,150	64,900
Same period, 1932	12	1	11	12,300	12	19,000	108,750





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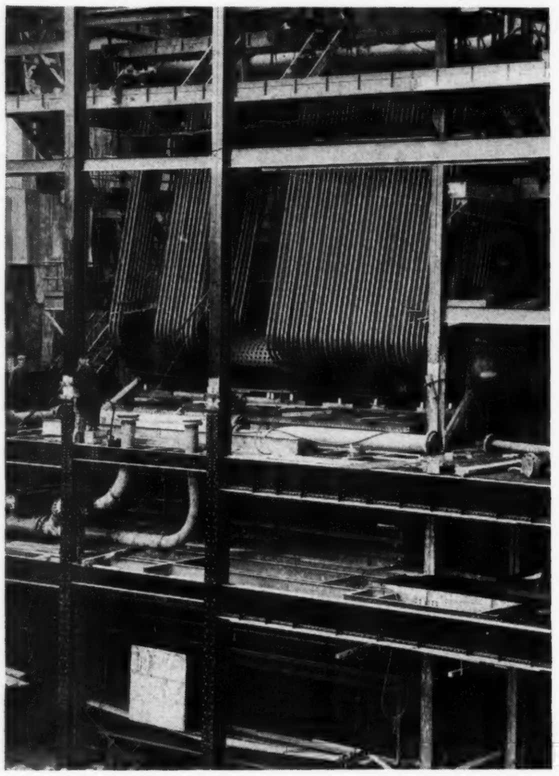

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East Port Washington Station, The Milwaukee Electric Rwy. & Light Company ***(being installed)***

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